

KLAMATH NETWORK WATER QUALITY REPORT (PHASE II)



Skull Cave, Lava Beds National Monument ,1968

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EXECUTIVE SUMMARY

The Klamath Network (KLMN) is one of 32 National Park Service (NPS) networks created to monitor and manage the long-term ecosystem health of the nation's parks. The park units of the Klamath Network are Crater Lake National Park (CRLA), Lassen Volcanic National Park (LAVO), Lava Beds National Monument (LABE), Oregon Caves National Monument (ORCA), Redwood National and State Parks (RNSP) and Whiskeytown National Recreation Area (WHIS). National Park Service networks are required to formulate Vital Signs Monitoring Plans, consisting of three phases: Phase I compiles background information and data on network park unit resources and presents conceptual models for each park unit ecosystem; Phase II provides an augmented Phase I and the selection and prioritization of vital signs; and Phase III will include the entire scope of information in Phases I and II, as well as the monitoring objectives, sampling designs and protocols, and data management and analysis procedures of a long-term vital signs monitoring program. The Klamath Network Phase II Water Quality Report is intended to provide an overview of the previous water quality related inventory and monitoring work conducted in each of the network's six park units and provide guidance in the direction of future monitoring objectives. The Phase II Report summarizes the activities undertaken to select vital signs to be used for monitoring the aquatic resources of Klamath Network park units.

The primary goal of the National Park Service Inventory & Monitoring (I&M) Program is to assess and monitor the long-term ecological health of park units. Other benefits of the program include the ability to detect change in resource condition and evaluate resource responses to management actions. Moreover, the program aims to create baseline knowledge of the condition of park unit resources for use by park unit scientists and those in academia or the private sector, and to create an effective method for data management, analysis, and reporting. Through information and data sharing the program hopes to increase public awareness of park unit activities and resources. To assess the ecological health of the park units the I&M program first focuses on inventories of park unit resources. While many aquatic resource-related inventories have been conducted within the Klamath Network, some fundamental inventories have not been completed. Then, given basic inventory data, a monitoring plan will be created to collect broad-based scientifically sound information on the current status and long-term trends in the health, composition, structure, and function of park unit ecosystems.

The I&M program was created through the Natural Resource Challenge, a method of improving natural resource stewardship in national parks. The Natural Resource Challenge requires managers to know the status or condition of natural resources under their stewardship and monitor long-term trends in those resources to conserve them unimpaired for future generations. Moreover, vital signs monitoring achieves the Category 1 goals found in the Government Performance and Results Act (GPRA) which requires that federal agencies account for money spent by reporting on the results of their activities.

To better understand and organize the information currently available about the aquatic resources of each park unit, the Klamath Network contracted the US Geological Survey to (1) compile background information on the primary aquatic resources of each network park unit,

including past and current monitoring efforts, and (2) draft the Phase II Report. To date, over 100 aquatic inventory and monitoring related projects have occurred within Klamath Network park units and surrounding public lands. These projects include information on aquatic biota (e.g. amphibians, fishes, macroinvertebrates), baseline water quality (e.g. chemical and physical parameters), hydrological/ geological resources (e.g. surface flow, groundwater, geothermal/hydrothermal, ice in ice caves), recreation effects, land use impacts, and watershed restoration.

The Klamath Network, under the guidance of the National I&M Program, undertook the process of creating conceptual ecological models to help identify proposed candidate vital signs for selection and prioritization. Conceptual models formalize understanding of natural processes and facilitate a cross-discipline dialogue between scientists and resource managers. In addition, conceptual models provide an understanding of the structure, function, and interconnectedness of park unit ecosystems, enabling the identification of vital signs for assessing ecosystem health. Models were developed for freshwater and marine aquatic ecosystems found in Klamath Network park units. The conceptual modeling process also identified many large-scale ecosystem-shaping processes, known as drivers. Drivers, as defined by the I&M program, are major forces of change that have large-scale influences on the attributes of natural systems. Drivers can be natural or human-induced and operate at the national or regional levels. The conceptual modeling process was particularly helpful in identifying proposed candidate vital signs that were not identified through other scoping processes.

The Klamath Network began its vital signs monitoring scoping process in 1998. Initial park-specific Vital Signs Workshops were held between 1998 and 2003 to begin to identify stressors that potentially impact park unit ecosystems. These workshops were followed in 2004 by three network-wide workshops. The purpose of these workshops was to more specifically identify monitoring questions and vital signs associated with specific ecosystems and ecosystem categories (e.g., air, soil quality, hydrology, water quality, invasive species, etc.). The result of these workshops was the development of 172 monitoring questions and associated vital signs for the various park unit ecosystems. These monitoring questions and vital signs were sent out for review and prioritization by scientists/resource managers with research and management expertise related to park unit ecosystems; and two of the 10 most important network-wide vital signs monitoring questions identified were aquatic-resource focused. These two questions were: (1) what is the status and what are the trends of surface waters and pollutants; and (2) what is the status and what are the trends in structure, function and composition of locally limited (i.e., focal) aquatic communities?

The dominant theme during the initial identification of network-wide water quality issues was aquatic ecosystem health. The ability to (1) document improvement (or lack thereof) in the water quality of Clean Water Act section 303(d) listed impaired streams, and (2) the ability of park unit managers to document progress toward achieving GPRA goal 1.a4 (i.e., that parks have unimpaired water quality), underscored the importance of identifying a suite of vital signs useful for effective water quality assessment. The need to fully inventory aquatic resources and document baseline and reference water quality conditions also were identified as important

objectives in the development of a vital signs-based long term water quality monitoring program.

Detailed assessment and refinement of priority issues specific to Klamath Network water quality and the two aquatic resource-focused monitoring questions began in October 2004. The process was initiated by sending an Aquatic Resources and Water Quality Questionnaire to the Chief of Resources Management of each park unit. Park-specific information was sought in five basic categories: (1) identification of aquatic resources within park unit boundaries (i.e., marine, estuarine, lotic, lentic, palustrine, ice caves, and geothermal/ hydrothermal); (2) a list of water bodies of particular importance or interest to the park unit management; (3) a list of past and current water quality monitoring efforts; (4) a list of water resource management and/or land use issues that impact resources from either within or outside each park unit; and (5) qualification of the level of knowledge and experience of park unit staff in monitoring water quality. Answers to the questionnaire categories were summarized into preliminary park-specific Vital Signs Tables that included columns for: (1) Aquatic Resource; (2) Potential Resource Stressors; (3) Potential Indicators of Stress; (4) Potential Monitoring Options; and (5) Stressor Priority. The tables were reviewed and refined at an aquatic resources vital signs scoping session held in December 2004. Park unit staff identified the five most significant water quality resource management issues and aquatic resource stressors for each park unit (i.e., climate change, land use and non-recreational human impacts, introduced/invasive non-native biota, visitor recreational activities, and atmospheric deposition of nutrients and pollutants). In addition, the assessment process was instrumental for identifying indicators (or vital signs) of aquatic resource stress, relative to the five identified stressors, and potential monitoring options for quantifying ecosystem health and/or disturbance. The park-specific and network-level results of this process are discussed in detail on pages 56-82.

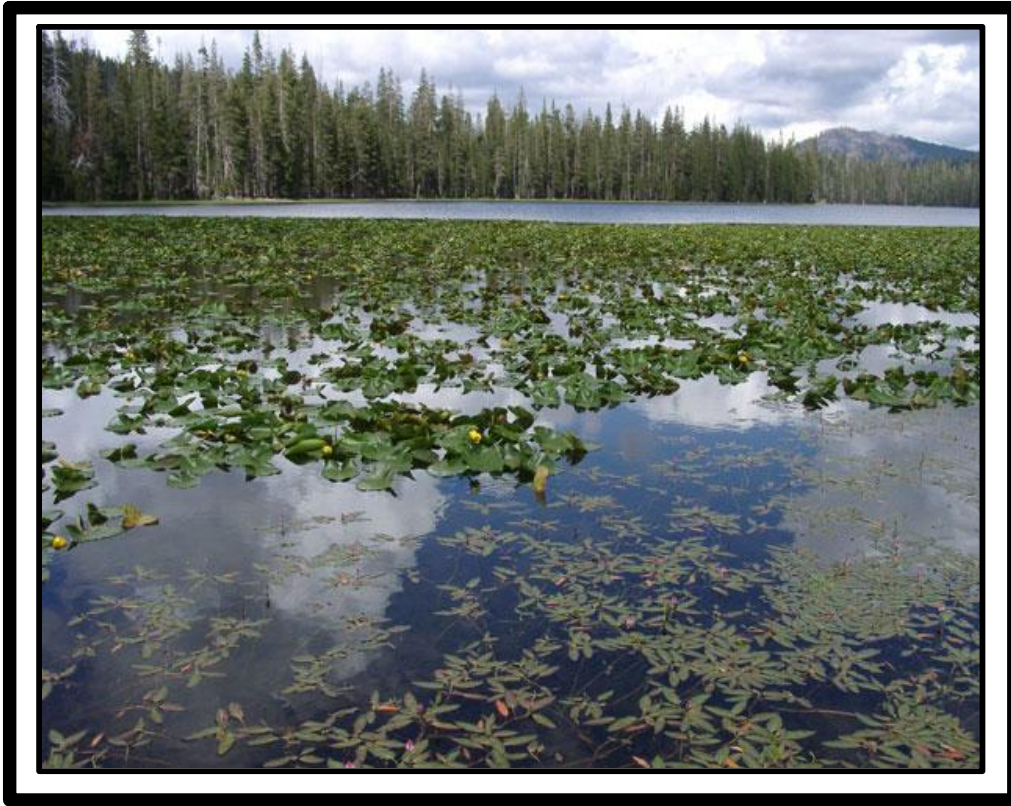


Figure 1. Horseshoe Lake, Lassen Volcanic National Park.

1.0 INTRODUCTION

The Klamath Network (KLMN) Water Quality Report is intended to provide a broad overview of aquatic resources (e.g., Figure 1) at the network and park unit levels. The report begins with an overview of aquatic resources of the Klamath Network and includes identification of the locations of active monitoring stations in or near park units where various parameters (e.g., precipitation, evaporation, temperature, general water quality) are measured. This overview is followed by a general discussion of past and present water quality inventory, monitoring, and research activities in each park unit, a list of references associated with these activities, and a review of common (i.e., network-wide) water quality inventory, monitoring, and research themes related to these activities. Past and present monitoring and research programs of allied agencies in the KLMN region are then discussed followed by a detailed review of the Klamath Network Vital Signs Scoping Process and park-specific/network-level outcomes. The final section of the report presents park-specific responses to the Aquatic Resources and Water Quality Questionnaire solicited from each park unit.

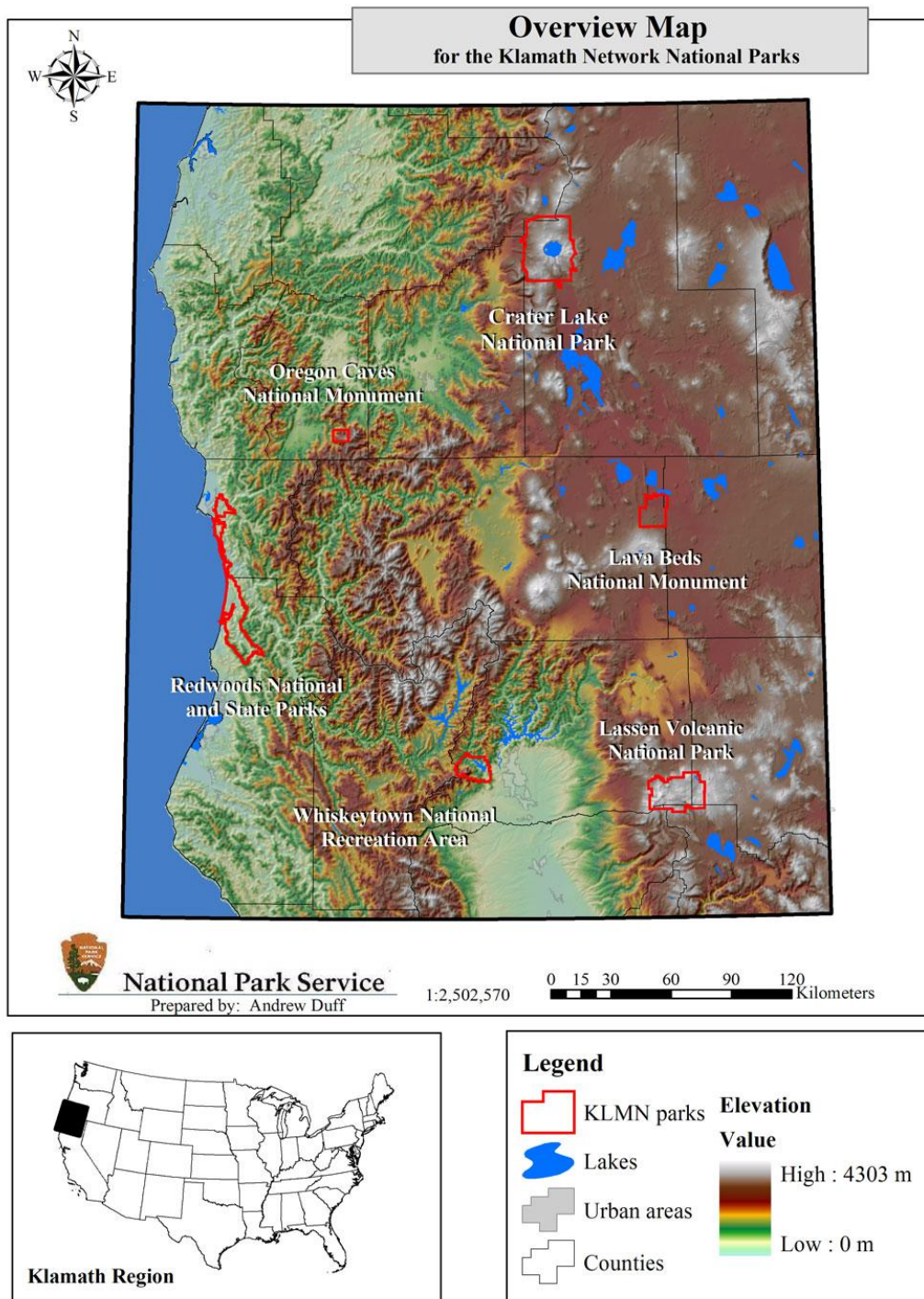


Figure 2. Klamath Network park units: Crater Lake National Park (CRLA), Lassen Volcanic National Park (LAVO), (Lava Beds National Monument (LABE), Oregon Caves National Monument (ORCA), Redwood National and State Parks (RNSP), and Whiskeytown National Recreation Area (WHIS). LAVO, LABE, and ORCA are the park units that have been selected for the current baseline inventory.

2.0 OVERVIEW OF KLAMATH NETWORK AQUATIC RESOURCES

The Klamath Network park units (Figure 2) occur in a rugged region of exceptional and complex climate, topography, and geology; and the aquatic resources within the network are very diverse. Crater Lake National Park (Crater Lake) is responsible for managing the clearest and seventh deepest caldera lake in the world. In addition, Crater Lake contains deep lake thermal areas, small ponds outside of the Mt. Mazama caldera, numerous streams and springs, and several important wetland areas. Lassen Volcanic National Park (Lassen) includes the largest concentration of freshwater lentic systems in the network, with over 250 ponds and lakes (many of which have never been inventoried), as well as several major stream drainages, geothermal areas, and sphagnum bogs along lake margins. Lava Beds National Monument (Lava Beds) has limited surface water, although Tule Lake and the Tule Lake Wildlife Refuge are present near the northern border of the Monument. Lava Beds does, however, have approximately 28 known ice caves that are an important source of water for wildlife and, historically, for humans. Oregon Caves National Monument (Oregon Caves) is a small unit with only one stream, Cave Creek. The creek flows through the main cave and wet meadows and seeps are present in the upper canyon of the creek. Parts of Cave Creek are directly affected by visitors touring the cave. Redwood National and State Parks (Redwoods) have marine and freshwater aquatic resources. Marine resources include over 60 km of coastal marine habitat extending 0.4 km offshore and coastal estuaries and lagoons. Freshwater resources include Redwood and Mill Creeks and their watersheds, and slope fens and seeps. Whiskeytown National Recreation Area (Whiskeytown) contains a large reservoir (Whiskeytown Lake) created by the damming of Clear Creek, as well as many perennial and intermittent tributary streams. Historically, mining was a common enterprise within WHIS and as a result acid mine drainage and mercury contamination are of major concern. WHIS also contains the only known global population of Howell's alkali grass (*Puccinellia howellii*) which is restricted to a mesosaline fen in the park.

2.1. National Park Service Water Resources Division Baseline Water Quality Inventory

The baseline water quality inventory is part of a National Park Service Water Resources Division program to develop baseline water-quality information for key resources in National Park Service units throughout the United States. A Klamath Network baseline inventory is in progress (i.e., 2005) at Lava Beds, Lassen, and Oregon Caves. The inventory is being conducted by personnel from the USGS Western Ecological Research Center located in Arcata, California. The following parameters have been measured for all water bodies selected for the inventory during the first of two sampling seasons scheduled to begin in 2005: alkalinity, dissolved oxygen, pH, specific conductance, temperature and discharge (where applicable). Additional parameters measured for select water bodies include fecal and total coliform, chloride, fluoride, nitrate and sulfate.

2.2 Outstanding Natural Resource Waters

There are no designated Outstanding Natural Resource Waters (ONRW) within the Klamath Network. Crater Lake National Park and network staff are, however, in the process of obtaining ONRW designation for Crater Lake from the Oregon Department of Environmental Quality.

The North Coast Regional Water Quality Control Board has identified Redwoods as a State Water Quality Protection Area as designated by the California State Water Board. Also, there are several Redwoods marine areas designated as Areas of Special Biological Significance by the State of California. The coast off Redwoods is part of a California Marine Sanctuary, and Redwoods has a California State Lands Commission Submerged Lands Lease to conduct resource management activities.

2.3 Wild and Scenic Rivers in the Klamath Network Region

(All of the information contained in this subsection is from the National Wild and Scenic Rivers website: <http://www.nps.gov/rivers/wildriverslist.html>.)

1. Eel River:

- A. **Designated Reach:** January 19, 1981. From the mouth of the river to 100 yards below Van Arsdale Dam. The Middle Fork from its confluence with the main stem to the southern boundary of the Yolla Bolly Wilderness Area. The South Fork from its confluence with the main stem to the Section Four Creek confluence. The North Fork from its confluence with the main stem to Old Gilman Ranch. The Van Duzen River from the confluence with the Eel River to Dinsmore Bridge.
- B. **Classification/Mileage:** Wild -- 97.0 miles; Scenic -- 28.0 miles; Recreational -- 273.0 miles; Total -- 398.0 miles.
- C. **Managing Agencies:** California Resources Agency, Bureau of Land Management; Six Rivers National Forest; Mendocino National Forest; Round Valley Reservation.

2. Klamath River:

- A. **Designated Reach:** January 19, 1981. From the mouth to 3,600 feet below Iron Gate Dam. The Salmon River from its confluence with the Klamath to the confluence of the North and South Forks of the Salmon River. The North Fork of the Salmon River from the Salmon River confluence to the southern boundary of the Marble Mountain Wilderness Area. The South Fork of the Salmon River from the Salmon River confluence to the Cecilville Bridge. The Scott River from its confluence with the Klamath to its confluence with Schackleford Creek. All of Wooley Creek.
- B. **Classification/Mileage:** Wild -- 12.0 miles; Scenic -- 24.0 miles; Recreational -- 250.0 miles; Total -- 286.0 miles.
- C. **Managing Agencies:** California Resources Agency; Yurok Tribe; Hoopa Valley Indian Reservation; Klamath National Forest; Bureau of Land Management.

3. Smith River:

- A. **Designated Reach:** January 19, 1981 and November 16, 1990. The segment from the confluence of the Middle Fork Smith River and the North Fork Smith River to its mouth at the Pacific Ocean. The Middle Fork from its the headwaters to its confluence with the North Fork Smith River, including Myrtle Creek, Shelly Creek, Kelly Creek, Packsaddle Creek, the East Fork of Patrick Creek, the West Fork Patrick Creek, Little Jones Creek, Griffin Creek, Knopki Creek, Monkey Creek, Patrick Creek, and Hardscrabble Creek. The Siskiyou from its headwaters to its confluence with the Middle Fork, including the South Siskyou Fork of the Smith River. The South Fork from its headwaters to its confluence with the main stem, including Williams Creek, Eightmile Creek, Harrington Creek, Prescott Fork, Quartz Creek, Jones Creek, Hurdgyurdy Creek, Gordon Creek, Coon Creek, Craigs Creek, Goose Creek, the East Fork of Goose Creek, Buch Creek, Muzzleloader Creek, Canthook Creek, Rock Creek, and Blackhawk Creek. The North Fork from the California-Oregon border to its confluence with the Middle Fork of the Smith River, including Diamond Creek, Bear Creek, Still Creek, the North Fork of Diamond Creek, High Plateau Creek, Stony Creek, and Peridotite Creek.
- B. **Classification/Mileage:** Wild -- 78.0 miles; Scenic -- 31.0 miles; Recreational -- 216.4 miles; Total -- 325.4 miles.
- C. **Managing Agencies:** California Resources Agency; Smith River National Recreation Area

4. Trinity River:

- A. **Designated Reach:** January 19, 1981. From the confluence with the Klamath River to 100 yards below Lewiston Dam. The North Fork from the Trinity River confluence to the southern boundary of the Salmon-Trinity Primitive Area. The South Fork from the Trinity River confluence to the California State Highway 36 bridge crossing. The New River from the Trinity River confluence to the Salmon-Trinity Primitive Area.
- B. **Classification/Mileage:** Wild -- 44.0 miles; Scenic -- 39.0 miles; Recreational -- 120.0 miles; Total -- 203.0 miles.
- C. **Managing Agencies:** California Resources Agency; Hoopa Valley Indian Reservation; Yurok Tribe; Shasta-Trinity National Forest; Six Rivers National Forest; Bureau of Land management

2.4 Clean Water Act Section 303(d) Impaired Waters

Table 1 lists the 303(d) impaired waters within the Klamath Network. Redwood Creek and the Klamath River in Redwoods are listed due to impacts associated with upstream land use practices; in particular, road building, reduced land cover as a result of logging, and dams. In Whiskeytown, Willow Creek (associated with past mining activities) and designated swim beaches of Whiskeytown Lake are listed as 303(d) impaired waters. Whiskeytown Staff are in the process of having the swim beaches delisted. A full discussion of the CWA Section 303(d) listing and Total Maximum Daily Load (TMDL) program process can be found at the following EPA web site: <http://www.epa.gov/owow/tmdl/> .

Table 1. Klamath Network 303(d) listed impaired water bodies.

303(d) Impaired Water	Pollutant/Stressor	TMDL Priority*
Klamath River (RNSP)	Temperature	High
	Nutrients	High
Redwood Creek (RNSP)	Temperature	Low
	Sedimentation/Siltation	Medium
Willow Creek (WHIS)	Metals	Low
Swim Beaches (WHIS)	Bacteria	Low

* See the EPA web site: <http://www.epa.gov/owow/tmdl/> for a description of the TMDL (Total Maximum Daily Loads) process.

2.5 Aquatic Species of Special Concern

In 2002, the Klamath Network began an inventory of vascular plants and vertebrate species of special concern in network park units (Acker *et al.* 2001). Aquatic vertebrate species of concern at the network-level include nine amphibian, five reptile, and four fish species. The study plan for this inventory is available at:

http://www1.nature.nps.gov/im/units/klmn/inventories/download_files/inventory_study_plan.doc.

A list of the 817 invertebrate and vertebrate species of special concern in the State of California is available as part of a report completed by the California Resources Agency. The report is available at: <http://www.dfg.ca.gov/whdab/pdfs/spanimals.pdf>.

A list of the 222 invertebrate and vertebrate species of special concern in the State of Oregon is available at: <http://www.pacificbio.org/ESIN/infopages/Oregonlist.html>.

3.0 LOCATIONS OF ACTIVE MONITORING STATIONS IN THE KLAMATH NETWORK PARK UNITS AND REGION

The following tables (1-7) list the locations of geo-referenced climatic and hydrologic monitoring stations in or near Klamath Network park units. In addition to these monitoring stations, past water quality sampling sites in or near Lassen, Lava Beds, Oregon Caves and Whiskeytown are listed in a Horizon Report for each park unit (i.e., LAVO = NPS-WRD 1999a, pages 51-54; LABE = NPS-WRD 1999b, page 39; ORCA = NPS-WRD 1998, page 45; WHIS = NPS-WRD 2000, pages 45-47). Horizon Reports have not been completed for Crater Lake and Redwoods. The Horizon Reports are baseline water quality data inventories that detail historical water quality sampling and monitoring efforts in network park units. These reports have been developed by the National Park Service Water Resources Division and Service-wide Inventory and Monitoring Program. The network will emphasize verifying and geo-referencing additional locations and will link spatial files with corresponding tabular records in the Dataset Catalog.

Table 2. Daily Precipitation Monitoring Stations.

Site	Latitude	Longitude	State
CRLA Headquarters	42.90000	-122.13333	OR
Crescent City	41.73333	-124.20000	CA
Crescent City 1N	41.76666	-124.06666	CA
Crescent City 1N	41.76666	-124.20000	CA
Crescent City 7ENE	41.78333	-124.08333	CA
Crescent City 7ENE	41.80000	-124.08333	CA
Crescent City 7ENE	41.80000	-124.23333	CA
Fort Dick	41.88333	-124.13333	CA
Fort Dick	41.88333	-124.15000	CA
Fort Dick	41.86666	-124.13333	CA
French Gulch	40.70000	-122.66666	CA
Klamath	41.51666	-124.03333	CA
LABE	41.73333	-121.51666	CA
Manzanita Lake-LAVO	40.53333	-121.56666	CA
Mineral	40.35000	-121.60000	CA
Mineral	40.35000	-121.58333	CA
Ono	40.48333	-122.61666	CA
Orick Prairie Creek Park	41.33333	-124.01666	CA
Orick Prairie Creek Park	41.36666	-124.01666	CA
Redding	40.58333	-122.40000	CA
Shasta Dam	40.71666	-122.46666	CA
Shingletown 2 E	40.50000	-121.26666	CA
Volta Power Station	40.46666	-121.56666	CA
Whiskeytown Reservoir	40.61666	-122.53333	CA
Williams 1 N	42.20000	-123.28333	OR

Table 3. Hourly Precipitation Monitoring Stations.

Site	Latitude	Longitude	State
Brandy Creek	40.61666	-122.70000	CA
CRLA Headquarters	42.90000	-122.13333	OR
Crescent City MNTC Station	41.75000	-124.20000	CA
Klamath	41.51666	-124.03333	CA
Mineral	40.35000	-121.60000	CA
Mineral	40.35000	-121.58333	CA
Sawyers Bar Ranger Station	41.30000	-123.98333	CA
Shasta Dam	40.50000	-121.26666	CA
Volta Power Station	40.46666	-121.56666	CA
Williams 1 N	42.20000	-123.28333	OR

Table 4. Evaporation Monitoring Stations.

Site	Latitude	Longitude	State
Brandy Creek	40.61666	-122.70000	CA
Crescent City MNTC Station	41.75000	-124.20000	CA
Klamath	41.51666	-124.03333	CA
Mineral	40.35000	-121.60000	CA
Mineral	40.35000	-121.58333	CA
Sawyers Bar Ranger Station	41.30000	-123.98333	CA
Shasta Dam	40.71666	-122.46666	CA
Volta Power Station	40.46666	-121.56666	CA
Whiskeytown Reservoir	40.61666	-122.53333	CA

Table 5. Air Temperature Monitoring Stations.

Site	Latitude	Longitude	State
CRLA Headquarters	42.90000	-122.13333	OR
Crescent City	41.73333	-124.20000	CA
Crescent City 1N	41.76666	-124.06666	CA
Crescent City 1N	41.76666	-124.20000	CA
Klamath	41.51666	-124.03333	CA
LABE	41.73333	-121.51666	CA
Manzanita Lake-LAVO	40.53333	-121.56666	CA
Mineral	40.35000	-121.60000	CA
Mineral	40.35000	-121.58333	CA
Orick Prairie Creek Park	41.33333	-124.01666	CA
Orick Prairie Creek Park	41.36666	-124.01666	CA
Redding	40.58333	-122.40000	CA
Shasta Dam	40.71666	-122.46666	CA
Whiskeytown Reservoir	40.61666	-122.53333	CA

Table 6. Drinking Water Intakes.

Site	Latitude	Longitude	Agency	State
Cave Junction-Illinois river	42.16111	-123.65000	City of Cave Junction	OR
Cave Junction Treatment Plant	42.15000	-123.63330	City of Cave junction	OR
Shasta Treatment Plant	40.58333	-122.48330	Shasta Comm Ser Dist	CA
Whiskeytown Reservoir	40.59917	-122.53830	Clear Creek Comm Ser Dist	CA
Whiskeytown Reservoir	40.59333	-122.46610	Shasta Comm Ser Dist	CA

Table 7. Stream Gaging Stations.

Site	Latitude	Longitude	Agency	State
Althouse Creek	42.08055	-123.51388	USGS	OR
Althouse Creek near Holland	42.10000	-123.52500	USGS	OR
Benner Creek	40.38388	-121.27333	USGS	CA
Butte Creek	40.64972	-121.27972	USGS	CA
Clear Creek at French Gulch	40.69500	-122.63555	USGS	CA
Clear Creek near Igo	40.51333	-122.52305	USGS	CA
Clear Creek near Shasta	40.62917	-122.56111	USGS	CA
East Fork Illinois River near Takilma	42.00278	-123.62500	USGS	OR
Elk Creek near Obrien	42.03166	-123.73666	BLM	OR
Elk Creek near Obrien	42.03167	-123.73666	USGS	OR
Illinois River at Kirby	42.19722	-123.65555	USGS	OR
Judge Francis Carr Powerhouse	40.64694	-122.62611	USGS	CA
Manzanita Creek-LAVO	40.53556	-121.57666	USGS	CA
Mill Creek near Mineral	40.35917	-121.50277	USGS	CA
South Fork Bailey Creek	40.47918	-121.59610	USGS	CA
Sucker Creek/Grayback Creek	42.15972	-123.47777	USGS	OR
Sucker Creek near Holland	42.15000	-123.46666	USGS	OR
Summit Creek near Mineral	40.36972	-121.53971	USGS	CA
West Fork Illinois River/Rock Creek	42.03888	-123.74722	USGS	OR
West Fork Illinois River near Obrien	42.06388	-123.71666	USGS	OR
West Fork Illinois River	42.05972	-123.72916	USGS	OR
Whiskeytown Lake	40.61750	-122.52527	USBR	CA
Whiskeytown Lake	40.61750	-122.52527	USGS	CA
Whiskeytown Lake	40.61666	-122.53333	USBR	CA
Windy Creek near Holland	42.13055	-123.36250	USGS	OR

4.0 PAST INVENTORY, MONITORING AND RESEARCH ACTIVITIES IN THE KLAMATH NETWORK PARK UNITS

In this section, past and ongoing water resources inventory, monitoring and research activities in each park unit are summarized based on information gathered from available project and study reports. A Horizon Report (or Technical Report of Baseline Water Quality Information and Analysis compiled by the National Park Service's Water Resources Division) has also been completed for four network park units (LAVO, LABE, ORCA, and WHIS). Each report contains information from several sources, including: (1) Storage and Retrieval (STORET) water quality database management system; (2) River Reach File (RF3); (3) Industrial Facilities Discharge (IFD); (4) Drinking Water Supplies (DRINKS); (5) Water Gages (GAGES); and (6) Water Impoundments (DAMS). Each report provides: (1) a complete inventory of all retrieved water quality stations and parameter data, and the entities responsible for data collection; (2) descriptive statistics and appropriate graphical plots of water quality data characterizing period of record, annual, and seasonal central tendencies and trends; (3) a comparison of the park's water quality data to relevant EPA and WRD water quality screening criteria; and (4) an Inventory Data Evaluation and Analysis (IDEA) to determine what Service-wide Inventory and Monitoring Program "Level I" water quality parameters have been measured within each study area. Core freshwater parameters include water temperature, specific conductance, pH, dissolved oxygen, qualitative assessment of flow/discharge at lotic sites, and qualitative assessment of stage/level at lentic sites. Marine/estuarine ecosystem core parameters include water temperature, dissolved oxygen, pH, conductivity, and salinity. Horizon Reports can be downloaded from the National Park Service's Water Resource Division web site at: (<http://www.nature.nps.gov/water/horizon.htm>).

4.1 CRATER LAKE NATIONAL PARK (CRLA)

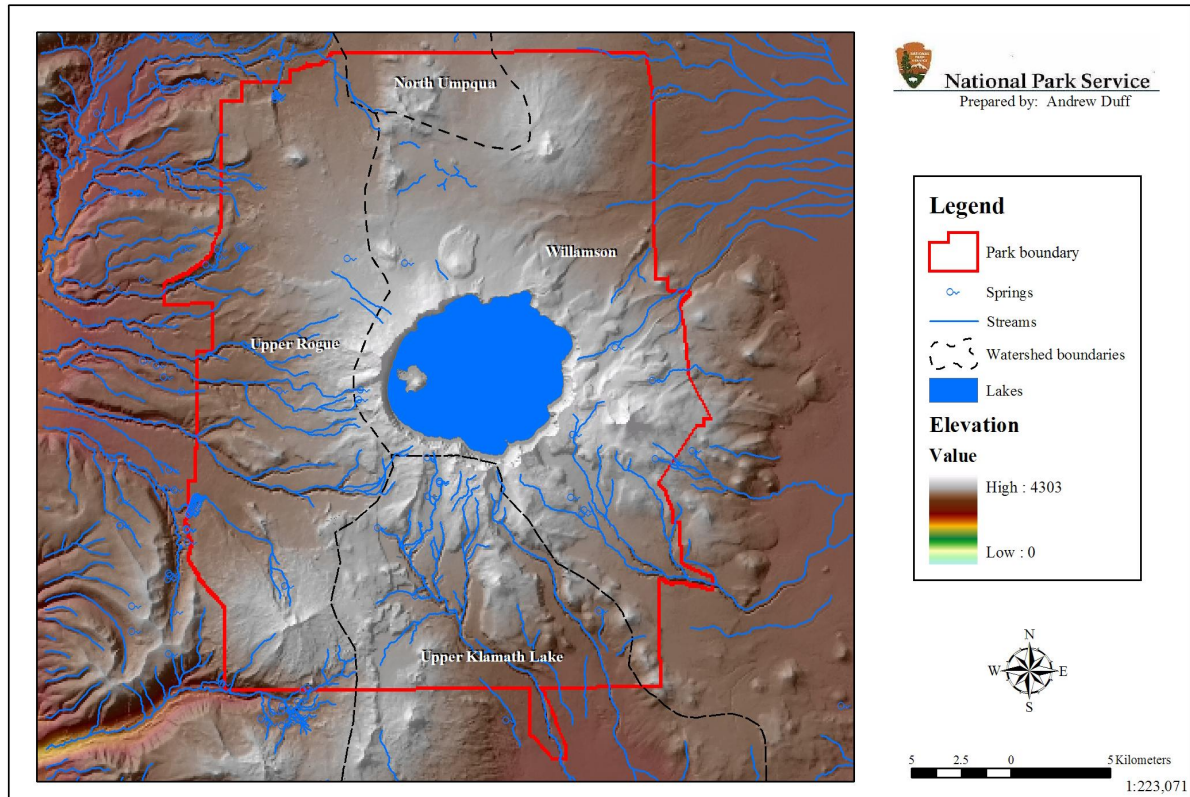


Figure 3. Aquatic resources and watershed boundaries of Crater Lake National Park.

Crater Lake National Park (Figure 3) was established by Presidential Proclamation on May 22, 1902. The 74,140 hectare (182,304 acre) park is located at the southern end of the Cascade Mountains in south-central Oregon. The park is dominated by a large natural caldera lake formed after the eruption of Mt. Mazama, approximately 7700 years ago (Ramsey et al. 2003; accessed June 6, 2005 at <http://geopubs.wr.usgs.gov/i-map/i2790/i2790.pdf>). The lake that is now in existence usually fluctuates seasonally between 1881 and 1882 meters in surface elevation. However, fluctuations of up to five meters have been recorded (Redmond 1990). Crater Lake is the clearest and seventh deepest lake in the world, and has a strikingly deep blue color. Secchi disk clarity readings have been recorded as deep as 40 meters.

The water quality of Crater Lake and other freshwater resources in Crater Lake National Park has been an important management focus for over 100 years. Water quality monitoring of Crater Lake began in 1892 when Diller and Patton initiated the recording of Crater Lake water level (Larson 1987). Numerous inventory, monitoring, and research projects and programs have been completed or are being conducted within the caldera and focused on Crater Lake, or at sites located outside of the caldera.

4.1.1 Intra-Caldera Monitoring and Research

Monitoring and research activities from 1892-1984 that were designed to document the physical, chemical, and biological characteristics of Crater Lake are listed in Table 8. Most of these activities were of short duration and limited in scope (Larson 1987). A long-term Crater Lake water quality monitoring program, that is now 22 years old, was initiated in June 1983. Sampling has been most often conducted during July, August, and September, however, sampling also has been conducted in January, March, April, May, June, and October. Samples for the determination of lake water quality have been collected at predetermined depths from 0–550 m, and from intra-caldera springs (Larson 1987, 1990, 1996). Initially, up to 41 springs were sampled, but this number was reduced to five springs beginning in 1990. Water quality variables monitored as part of the long-term monitoring program (1983-present) are listed in Table 9. Introduced rainbow trout (*Oncorhynchus mykiss*) and kokanee salmon (*Oncorhynchus nerka*) have also been studied as part of the monitoring program. Detailed information concerning the long-term water quality monitoring program is available in Larson 1987, 1990, and 1996.

Table 8. Highlights of Crater Lake monitoring and research activities, 1892-1984 (from Larson 1987).

Date	Activities
1892	Water level records initiated
1896	First scientific expedition (temperature and transparency)
1912	First chemical analysis (one sample from a depth of 2 m)
1913	Temperature, dissolved oxygen, Secchi disk, phytoplankton and zooplankton
1935	Optical properties (color)
1934-1936	Temperature, light transmission, and general floral and faunal surveys
1937-1940	Temperature, Secchi disk, and fish investigations
1938-1939	Secchi disk
1940	Temperature, dissolved oxygen, carbon dioxide, light transmission, nutrients and phytoplankton
1947/1950	Diatoms
1954	Secchi disk
1959	Morphometry
1960	Sediments evaluated
1961-1964	Stage height and temperature recorders installed, chemical analysis
1966	Temperature and general observations of surface current patterns
1967-1969	Distribution patterns and population dynamics of zooplankton, physical and chemical limnological characteristics, primary production and chlorophyll-a
1978-1981	General limnological characteristics with emphasis on phytoplankton distribution and abundance
1982-1984	Baseline monitoring program underway (physical, chemical, phytoplankton, with chemical and bacterial studies of caldera wall springs; hydrothermal springs located on lake bottom; sedimentation studies initiated)

Table 9. Crater Lake and intracaldera springs water quality variables monitored as part of the Crater Lake Long-term Monitoring Program (1982-present).

Variable	Location
Temperature	Lake and Spring
Lake level	Lake
Secchi disk depth	Lake
Light transmission and penetration	Lake
pH	Lake and Spring
Alkalinity	Lake and Spring
Specific conductance	Lake and Spring
Dissolved oxygen	Lake
Total phosphorus	Lake and Spring
Orthophosphate	Lake and Spring
Nitrate-nitrogen	Lake and Spring
Total Kjeldahl nitrogen	Lake and Spring
Ammonia-nitrogen	Lake and Spring
Sulfate	Lake and Spring
Silica	Lake and Spring
Chloride	Lake and Spring
Sodium	Lake and Spring
Calcium	Lake and Spring
Magnesium	Lake and Spring
Potassium	Lake and Spring
Sulfur	Lake and Spring
Iron	Lake and Spring
Bacterial studies	Lake
Chlorophyll-a	Lake
Primary production (C^{14} light/dark bottles)	Lake
Phytoplankton (species, density, biomass)	Lake
Zooplankton (species, density, biomass)	Lake
Fish (species, abundance, biomass, spatial distribution, age, sex, growth, and food habits)	Lake
Hydrothermal processes studies	Lake

4.1.2 Extra-Caldera Monitoring and Research

The first observations documenting aquatic resources outside of the Crater Lake caldera were published in 1929 and 1935 in the park's Crater Lake Nature Notes publication. These articles identified and described, respectively, several mineral springs in the Annie Creek Canyon and six waterfalls that occurred at several locations in the park. Numerous articles in Crater Lake Nature Notes, survey reports, and articles published in peer-reviewed scientific journals have, since the publication of those two early articles, documented the diverse types of aquatic resources present in the park. The first survey of park streams was completed in 1947 (Wallis 1948). This survey, focused primarily on trout distribution, included 41 stations on 19 streams where water temperature, average station width and depth, and velocity were measured and stream habitat was described. A more extensive survey of park streams and springs was conducted in 1967-1968 (Frank & Harris 1969). These surveys recorded 106 flow measurements for 46 streams and 21 springs, and collected 45 water samples from a subsample of 17 streams and 21 springs. Eight samples were analyzed for a complete suite of water quality variables, and 37 samples were analyzed for a subset of variables. In 1981–1985, approximately 10 springs were sampled for water chemistry analysis (Thompson *et al.* 1987). The Whitehorse Ponds, a complex of 15 ponds located on Whitehorse Bluff, were inventoried and sampled in 1992 and 1993 to document their physical, chemical, and biological characteristics (Salinas *et al.* 1994). Additional activities have included: (1) incidental observations and projects designed to survey and investigate the distributions and life history characteristics of amphibian species in Crater Lake and at freshwater sites outside of the caldera (e.g., Farner 1947, Farner & Kezer 1953, Kezer & Farner 1955, Bergmann 1997); and (2) a project to eradicate brook trout (*Salvelinus fontinalis*) from and restore native bull trout (*Salvelinus confluentus*) in Sun Creek. The bull trout restoration project was initiated in 1992 in response to the precipitous decline within the park of this genetically distinct Pacific Northwest population due to encroachment of introduced nonnative brook trout. Fish surveys of all Klamath River basin tributaries within the park have also been conducted.

Horizon Report

No report is presently available.

Water Quality Concerns

- 1) An extensive inventory of all aquatic resource locations within the park boundary and ArcGIS feature datasets is to be completed in 2006
- 2) Long-term clarity of Crater Lake and health of the lake ecosystem

See Attachment I for CRLA water quality, fisheries and streams inventory, monitoring, and research study references.

4.2 LASSEN VOLCANIC NATIONAL PARK (LAVO)

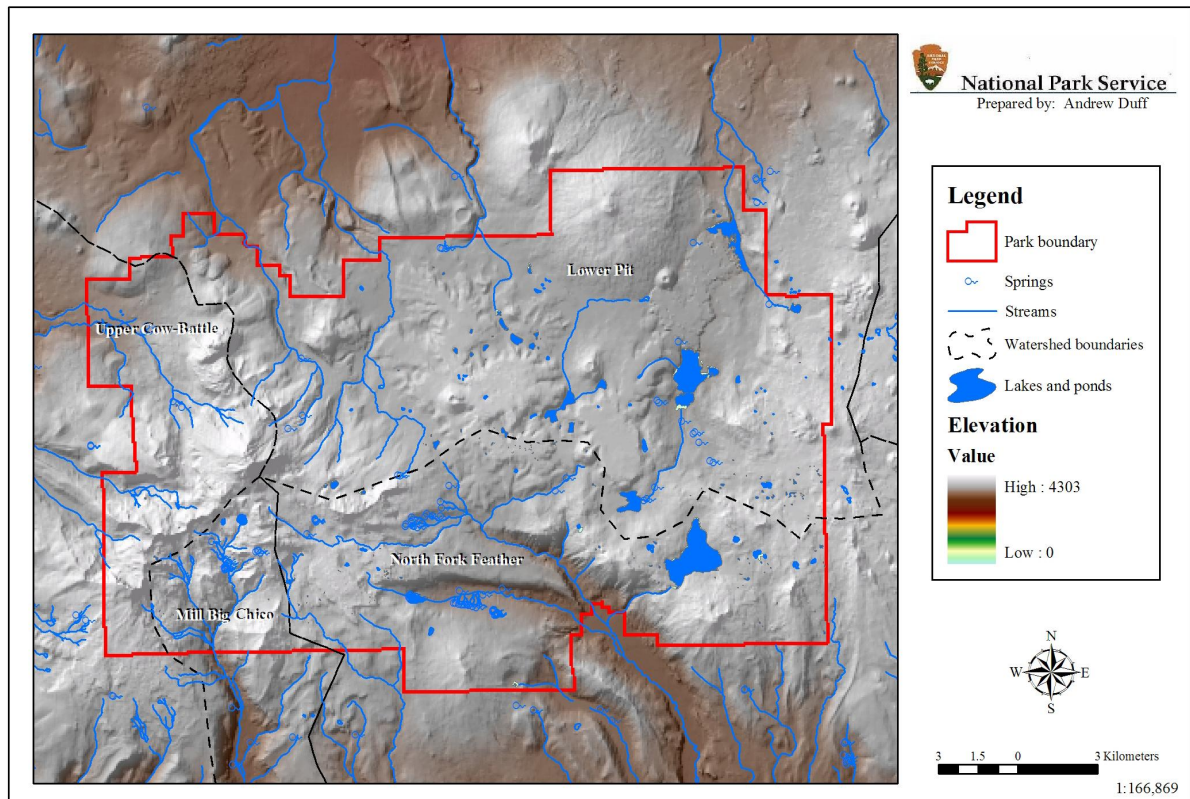


Figure 4. Aquatic resources and watershed boundaries of Lassen Volcanic National Park.

Lassen Peak and Cinder Cone National Monuments were established on March 6, 1907, and combined into Lassen Volcanic National Park (Figure 4) on August 9, 1916. The park is located in the southern most part of the Cascade Mountains in northeastern California, and is part of the Cascade Physiographic Province. The park is 43,047 hectares (106,372 acres) in size and the landscape is dominated by volcanic processes and Lassen Peak is the southernmost volcano in the Cascade Range. However, the park contains up to 277 permanent and ephemeral lentic water bodies. Portions of five drainage basins are located within the park, and four of the drainage basins (about 99% of the park) drain into the Sacramento River. All of the lakes and streams in the park are considered important for wildlife and several receive high visitor recreational use. Many lakes have been historically stocked with nonnative trout for recreational fishing and now contain self-propagating populations. Mill Creek, which has no dams blocking anadromous fish passage, is one of very few stream courses remaining in the Sacramento River drainage with biological integrity preserved.

There are several aquatic vertebrate and invertebrate taxa within Lassen that are on the federal and/or state lists as protected species. Kings Creek Caddisfly (*Parapsyche extensa*) is a federal species of concern; the Modoc Sucker (*Catostomus microps*) is listed as endangered on both lists; and the Cascades Frog (*Rana cascadae*) is listed as a federal and state species of concern.

Horizon Report

The retrieval of surface water quality data from six of the US Environmental Protection Agency's (EPA) national water resources databases collected data generated by four agencies (i.e., National Park Service [NPS], US Geological Survey [USGS], EPA, and California Water Resources Control Board [CWRCB]; NPS-WRD 1999a). These data represent water quality analyses for samples collected from 281 sampling stations, of which 218 (NPS = 190, USGS = 14, EPA = 7, CWRCB = 7) were within the boundaries of Lassen. Park sampling stations (NPS-WRD 1999a, pages 51-54) were located at 29 lakes, 21 cold and hot streams, 60 hydrothermal sites, and 2 wetlands. Some sites had multiple sampling stations. A total of 169 water quality parameters (NPS-WRD 1999a, pages 55-57) were examined, although not all parameters were represented at all sampling locations. The period of time represented by these data from Lassen sampling sites was 1960-1994. The Horizon Report is available at: (http://nrdata.nps.gov/LAVO/nrdata/water/baseline_wq/docs/LAVOWQAA.pdf).

Lakes, Streams, and Wetlands

The first known survey of lakes in Lassen was documented in a report titled "1955 Lake Survey – Lassen Volcanic National Park" (author unknown). This was followed by a 1958 fishery resources survey of 22 lakes (Wallis 1959). The purpose of this survey was to develop a stocking plan for park lakes and was concerned primarily with fish species distributions and past stocking activities. Several lake surveys were conducted during the 1960's and data from these surveys have been summarized in the Baseline Water Quality Data Inventory and Analysis report described previously (NPS-WRD 1999a). At least 11 lakes were surveyed during this period of time. The objectives of these surveys were to determine the general ecological conditions of the lakes and to develop management and research alternatives for the park's lentic resources. In 1976, an extensive survey of Lassen lakes was completed (West 1976). A total of 162 lentic systems were inventoried, and of these 131 were surveyed. Survey measurements and assessments included: (1) water temperature; (2) color; (3) clarity; (4) site depth (maximum and mean); (5) site bottom and shore type; (6) watershed condition; (7) site surface area; (8) presence and location of inlets and outlets; (9) fish presence; (10) presence of fish predators; and (11) relative abundance of aquatic invertebrates and vegetation. Additional lake survey activities included the physical and chemical analysis of seven Lassen lakes as part of the EPA's Western Lake Survey (Landers *et al.* 1987, Eilers *et al.* 1987); the inventorying of aquatic invertebrates (DeMartini, 1994); and amphibian surveys of 378 lentic sites as part of the Amphibian Research and Monitoring Initiative (Fellers *et al.* 2003). Stead *et al.* (2005), during the summer of 2004, also investigated the status of native amphibians and nonnative fish in Lassen lentic habitats (i.e., lakes, permanent and temporary ponds, wet meadows, and marsh/bogs; n=365). A new baseline water quality inventory of Lassen aquatic resources will begin in 2005, conducted by personnel of the USGS Western Ecological Research Center in Arcata, California.

Stream (cold and hot) and wetland survey data are available as part of the Baseline Water Quality Data Inventory and Analysis Report (NPS-WRD 1999a). Three reports document stream survey activities from 1963-1979 (Everest 1964, McClelland 1973, Thompson 1983), and three agencies (i.e., NPS, USGS, and CWRCB) have been responsible for collecting stream

survey data from 1979-present. Two wetlands (Corral Meadows and Grassy Swale) were surveyed as part of the Lassen Park Summer 1979 Lake Surveys, and research has been conducted on the Drakesbad fen from 2002-2004 (Patterson and Cooper, in prep). A sanitary survey of five park watersheds supplying water to campgrounds and park communities was completed in 1996. The survey was conducted by faculty of the Department of Civil Engineering and Applied Mechanics, San Jose State University. The survey brought the park into compliance with the USEPA Surface Water Treatment Rule established in 1989 and provided information concerning water source water quality and types and sources of potential water source contamination. Survey results are available as a report prepared for the park by Williamson *et al.* (1997).

Hydrothermal/Geothermal Resources

Geothermal/hydrothermal resources in Lassen are situated primarily in the southwestern (e.g., Sulfur Works, Bumpass Hell, Little Hot Springs Valley) and southern (e.g., Devil's Kitchen, Drakesbad, Terminal Geyser) parts of the park (Thompson 1983). Waring (1915) reported the results of the first thermal water analyses of Lassen hot springs. Ten years later, Day and Allen (1925) reported the results of the chemical analyses of water from 23 Lassen hot springs. Since these early analyses, there have been at least five surveys of hydrothermal resources during the period 1963-1981 (e.g., Lenn 1965 = 22 hot springs; Ghiorso 1980 = 34 hydrothermal sites; Thompson 1983 = 43 hydrothermal sites). Data from these surveys have been collected in the Baseline Water Quality Data Inventory and Analysis (NPS-WRD 1999a). Since 1981, the monitoring and chemical analyses of Lassen hydrothermal sites have been performed primarily by the USGS. According to USGS Fact Sheet 101-02 (Clynne *et al.* 2002), NPS personnel and USGS scientists continuously monitor the physical and chemical characteristics of surface hydrothermal activity in the park to: (1) better understand the origin and evolution of the park's hydrothermal resources; and (2) protect park visitors from any potential hazards associated with visiting these features.

Fisheries Studies

- 1) Management of fishing and fish stocking in National Parks in California, 1975.
- 2) Management of high country lakes in the National Parks of California, 1976.
- 3) Snag Lake Management Report, 1976.
- 4) Summary of 1976 lake survey data relating to the status of trout fisheries in Lassen Volcanic National Park.
- 5) An analysis: Impacts of trout stocking upon recreational fishing and aquatic resources in Lassen Volcanic, Sequoia and Kings Canyon, and Yosemite National Parks, California, 1977.
- 6) Food Habits Analysis of Fish from Mountain Lakes in Lassen Volcanic National Park, California. 1977.
- 7) Aquatic resources of Lassen volcanic, Sequoia-Kings Canyon, and Yosemite National Parks, with special reference to trout stocking and the recreational fishery, 1978.
- 8) Status of the Manzanita Lake trout fishery, Lassen Volcanic National Park, 1998.
- 9) Surveys of the Sifford Lakes, Lassen Volcanic National Park, 2000.

- 10) FY04 Joint inventory of fishes, native amphibians, and invertebrates in all lakes and ponds of the park. Status of the trophy rainbow trout fishery at Manzanita Lake (Lassen Volcanic National Park) based on reports from angler survey boxes in 1994.

Water Quality Concerns

- 1) An extensive inventory of all aquatic resources within the park boundary and ArcGIS datasets was completed in 2004

Deterioration of geothermal areas as a result of visitor impacts

See Attachment I for LAVO water quality, fisheries and lake monitoring and research study references

4.3 LAVA BEDS NATIONAL MONUMENT (LBE)

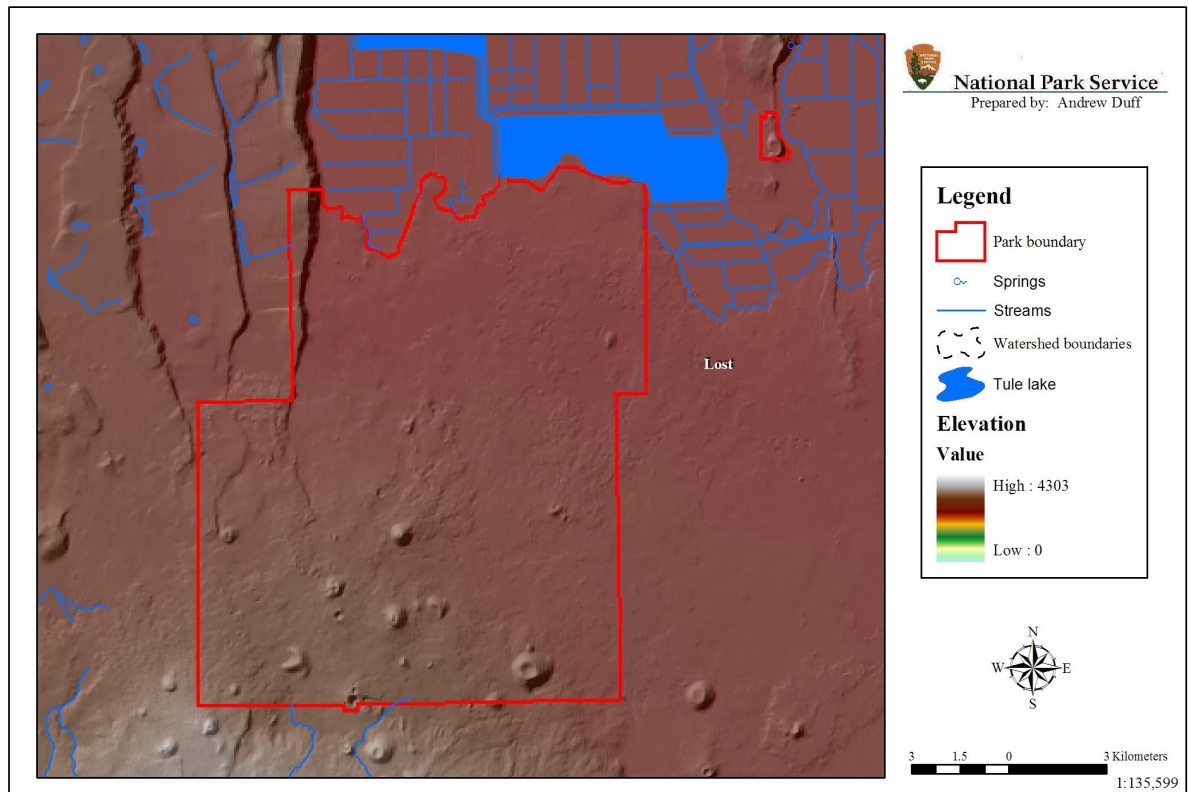


Figure 5. Aquatic resources and watershed boundaries of Lava Beds National Monument.

Lava Beds National Monument (Figure 5) was established by Presidential Proclamation on November 21, 1925 to preserve for public enjoyment the area's dramatic volcanic geology (e.g., lava tubes, cinder cones, spatter cones, lava flows and other volcanic phenomena). Lava Beds was originally placed under the jurisdiction of the Department of Agriculture, U.S. Forest Service, and was transferred to the Department of the Interior on June 10, 1933.

The 18,842 hectare (46,560 acre) monument is located on the east-side of the Southern Cascade Mountains on the Modoc Plateau in northeastern California. The plateau is a volcanic platform generally ranging in elevation between 1219–1829m (4,000- 6,000 ft). Lava Beds lies on the northern flank of Medicine Lake Volcano. The volcano is a Pleistocene to Holocene shield volcano located about 48.3 km (30 miles) northeast of Mt. Shasta and the eruptive area of the Medicine Lake Volcano covers over 233 km² (900 mi²). There is evidence of glaciation at the higher elevations of the volcano. LBE contains a range of Great Basin vegetation communities, including ponderosa pine forests, mountain mahogany/juniper, and sagebrush/bunchgrass.

Lava Beds currently has 502 documented lava tube caves with a total of 46.2 km (28.7 miles) of known passageways. Due to the porosity of lava soils, no permanent ponds, lakes, streams or wetlands are found within the monuments boundary. However, 28 caves within the monument

are documented to contain ice and water, and seasonal (intermittent-ephemeral) ponds can be formed after heavy precipitation events. Many of the ice caves are important water sources for wildlife and have been historically used by humans (e.g., indigenous groups, ranchers and moonshiners). Fourteen species of bats and a number of bird species utilize the ice caves as sources of water. Two of the bat species include Townsend's big eared bat (*Corynorhinus townsendii*) which is a species of concern, and the largest northern migratory United States colony of the Mexican free-tail bat (*Tadarida brasiliensis*).

There are no distinct aquifers in the area, so there is uncertainty about the source, quantity and movement of groundwater in Lava Beds. One groundwater well, located at the monument headquarters, provides water for all staff and visitors. The U.S. Geological Survey is monitoring groundwater at five wells, four in the monument and one outside the monument boundary. There appears to be some groundwater drawdown due to agricultural land use near the monument. The National Park Service Water Resources Division is helping to evaluate the status of groundwater at Lava Beds.

In 1999, a Student Conservation Associate conducted the first water sampling of 14 Lava Beds ice caves. Between 1990 and the present, eight ice cave floors have been monitored for changes in ice depths by the Cave Research Foundation. In 1999, the ice in Merrill Ice Cave, one of the larger ice resources in the monument, began to melt with the formation of a hole in the center of the ice floor (Figure 6). By 2001, the entire ice resource had practically disappeared. It is paramount that an ice/water quality baseline be established before possible future losses occur in other caves.

The Glass Mountain Known Geothermal Resource Area (KGRA) is located adjacent to Lava Beds to the south. The KGRA allows the Bureau of Land Management to conduct competitive lease sales for geothermal exploration. In the past there has been exploratory drilling for geothermal resources in the Medicine Lake area up to the southern boundary of the monument. Although, it is unlikely that any wells will be drilled in the monument, outside activity could have an impact on Lava Beds. There could be a drawdown of the groundwater table in addition to the vibration and disturbance caused by the drilling rigs and support activities.

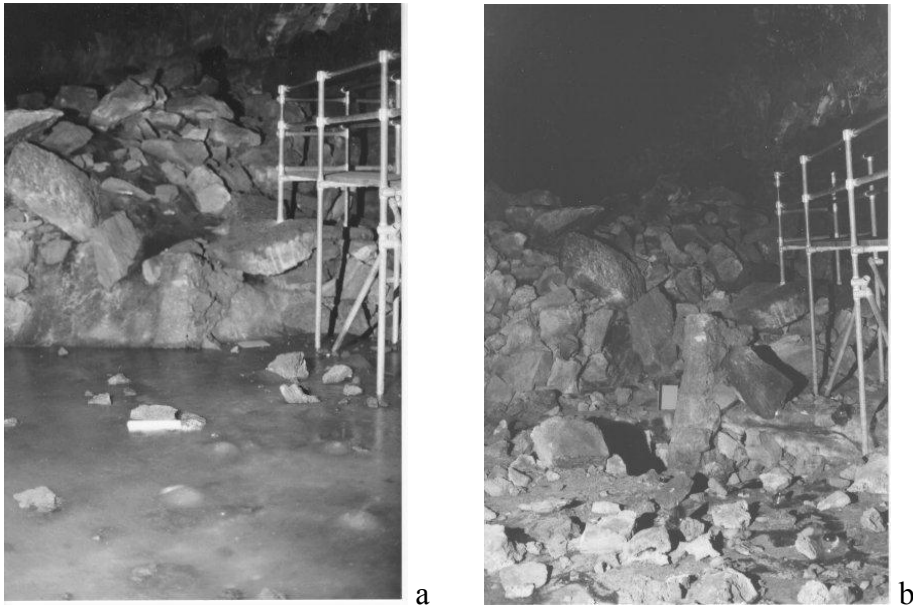


Figure 6. Merrill Cave ice floor in (a) 1990 and (b) 1999.

Horizon Report

A Horizon Report (NPS-WRD 1999b) is available for Lava Beds at: (http://nrddata.nps.gov/LABE/nrddata/water/baseline_wq/docs/LABEWQAA.pdf). Data were collected for 131 water quality parameters (pages 40-41 of the report) from 23 sampling stations (page 39 of the report) from 1966 through 1992. The stations were outside of the park unit boundary and associated with Tule Lake. The U.S. Geological Survey and the National Park Service were responsible for the water quality sampling summarized in this report.

Ice and Water Resource Monitoring

- 1) Ice cave studies
- 2) Groundwater study
- 3) Water quality inventory within ice caves (KLMN-FY05, Chris Currens, USGS WERC). Beginning in 2005, water sampling at Lava Beds will occur in 12 of the 28 known ice caves. Sampling will occur in caves identified as primary ice resources for the monument. The selection of caves will also be based on ease of access, technician safety, and cave resource sensitivity
- 4) Ice levels in eight ice caves have been monitored since 1990 by Cave Research Foundation
- 5) Ice cave geomorphology
- 6) Effects of geothermal exploration and development
- 7) Assess effects of adjacent land use practices on park unit resources (agricultural use, insecticides/pesticides; accumulation within Tule Lake; Tule Lake NWR management/land use)

Water Quality Concerns

- 1) Loss of ice in permanent ice caves and water in seasonal wet caves
- 2) Lack of data on groundwater supply and possible drawdown effects
- 3) Lack of basic water quality inventory of intermittent-ephemeral ponds

See Attachment I for LABE water quality inventory, monitoring and research study references.

4.4 OREGON CAVES NATIONAL MONUMENT (ORCA)

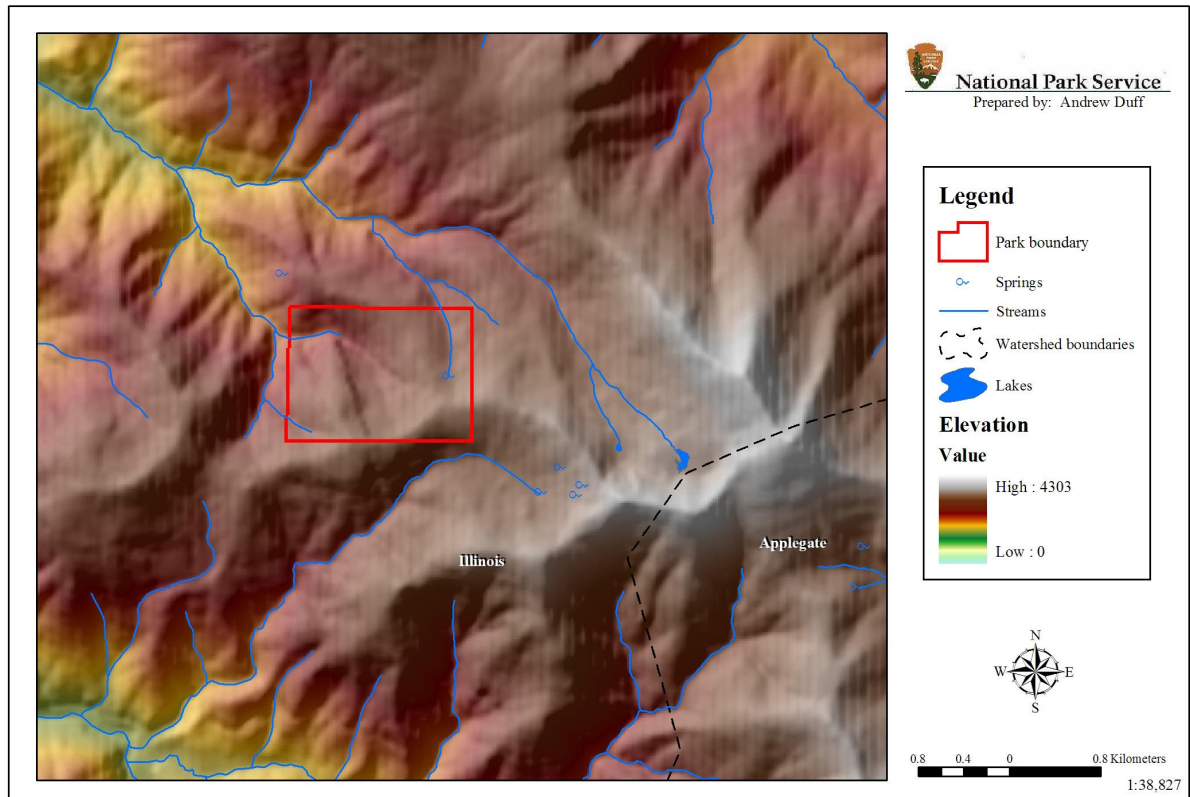


Figure 7. Aquatic resources and watershed boundaries of Oregon Caves National Monument.

Oregon Caves National Monument (Figure 7) was established on July 12, 1909, under the U.S. Forest Service, specifically to protect the cave system. It was transferred to the National Park Service on August 10, 1933. In February 1992, a large portion of the developed area in the monument was listed in the National Register of Historic Places. Oregon Caves (194 hectares; 480 acres) is located in the Siskiyou/Klamath bioregion of southwestern Oregon. Although Oregon Caves is a small unit, its forest communities are a diverse representation of the larger bioregion. Old growth Douglas fir, white fir and oak forests cover the majority of the monument, providing diverse microhabitats for the monument's nearly 500 plant species, and an estimated 5,000 animal and 2,000 fungal species; which are among the highest catalogued biota per acre for any national park unit (John Roth, ORCA, personal communication). Federally threatened and endangered species that reside in or utilize the monument include the northern spotted owl, bald eagle, and peregrine falcon. Two of the 20 federal and state species of concern in the monument are the Del Norte Salamander (*Plethodon elongates*) and Western Toad (*Bufo boreas*). The amphibian species are, respectively, a species of concern and a sensitive species in the State of Oregon. The cave pools, springs and streams of Oregon Caves are considered important water resources for wildlife.

Horizon Report

A Horizon Report (NPS-WRD 1998) for Oregon caves is available at: (http://nrddata.nps.gov/ORCA/nrddata/water/baseline_wq/docs/ORCAWQAA.pdf). Water quality data catalogued in this report were provided by the Washington Department of Ecology, US Forest Service-Region 6, US Geological Survey, National Park Service, and US Environmental Protection Agency-Region 10. Nineteen sampling stations (page 45 of the report) were located in the park unit; 11 in the cave and 8 outside of the cave. A total of 30 water quality parameters (page 46 of the report) were measured and sampled. The period of sampling was 1966 and 1992-1993.

Cave Inventory

According to Roth (1994), the first comprehensive inventory of any large federally managed cave in the US was completed at Oregon Caves by Earthwatch Institute volunteers prior to 1994. The physical characteristics and magnitude of potential direct human impacts (as indicated by the presence of “cave slime” or *actinomyces* bacteria) on Oregon Caves were inventoried.

Aquatic Studies

- 1) ORCA sample collection, 1992-1993, baseline water quality inventory of waters in or near the cave system;
- 2) Within-cave water quality study of Cave Creek (ongoing by John Salinas, Rogue Valley Community College)
- 3) Water quality inventory (KLMN-FY05, Chris Currens, USGS WERC)

Water Quality Concerns

- 1) Decline in water quality due to human-caused organic enrichment, calcite solubility index, and turbidity
- 2) Changes in water volume and timing of cave infiltration
- 3) Contamination of Cave Creek (the primary water resource at ORCA), cave springs and other surface streams due to drain field pollution and pavement-derived hydrocarbon particulate input
- 4) Changes in the caves environment (including Cave Creek and various springs located inside the cave) due to manipulation of the primary cave’s environment (i.e., modified cave opening and lighted walkway
- 5) Visitor use
- 6) Protection, preservation, restoration and interpretation of cave and karst are of primary importance to the park unit.

See Attachment I for ORCA water quality inventory, monitoring and research study references.

4.5 REDWOOD NATIONAL AND STATE PARKS (RNSP)

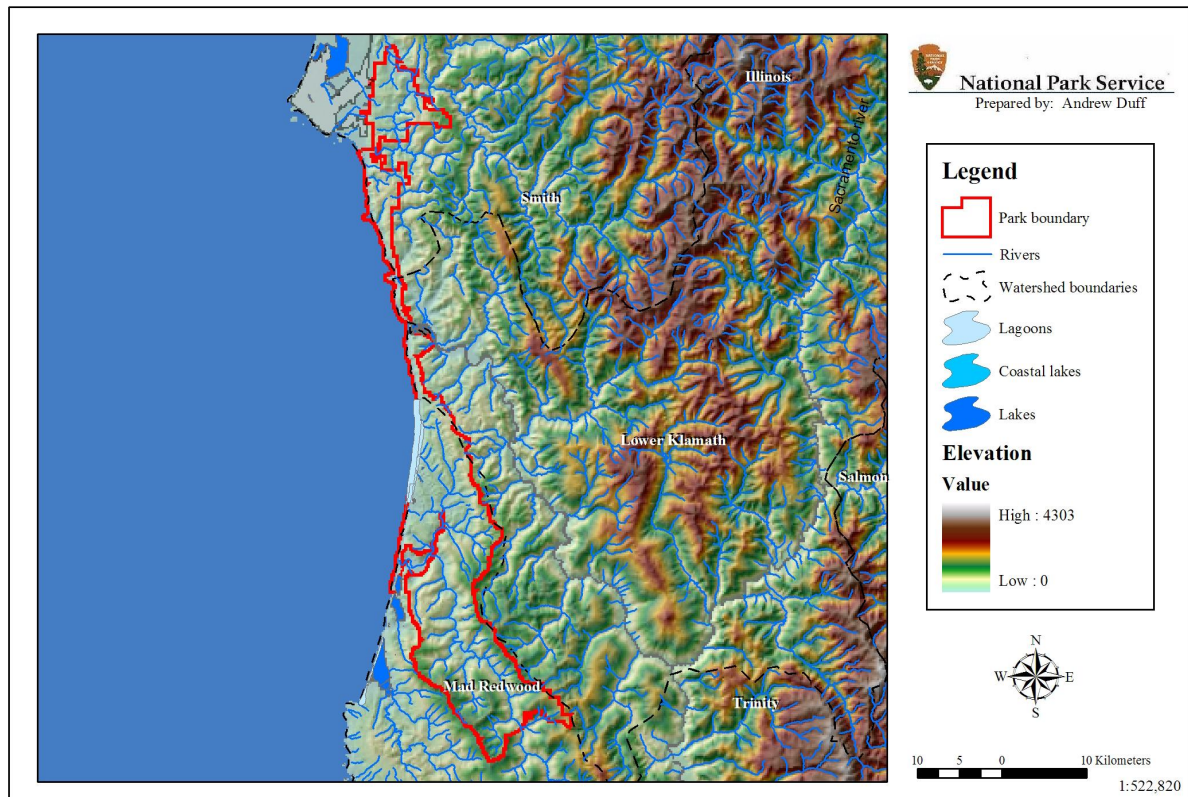


Figure 8. Aquatic resources and watershed boundaries of Redwood National and State Parks.

Redwood National Park was established on October 2, 1968. It was designated a World Heritage Site on September 5, 1980, and a Biosphere Reserve on June 30, 1983. Redwood National Park joined three California State Parks as one cooperative management unit of the National Park Service and California Department of Parks and Recreation. The state parks are: Prairie Creek Redwoods State Park, Del Norte Coast Redwoods State Park, and Jedediah Smith Redwoods State Park. In May 1994, Redwood National Park became Redwood National and State Parks (Figure 8), which contains approximately 45% of all remaining old-growth redwood forest in California. The parks are 42,701 hectares (105,516 acres) in size arrayed along the Pacific Coast of northern California. The western boundary of Redwoods extends 0.4 km (0.25 miles) beyond the mean high tide line of the Pacific Ocean and the National Park Service has jurisdiction over the waters, intertidal lands, and submerged lands in this area. The coastal jurisdiction of state parklands extends 0.3 km (0.19 miles) west of the ordinary high-water mark of the Pacific Ocean. Elevations within the park range from below sea level to 996 m (sea level-3268 feet).

The aquatic resources of Redwoods consist of over 60 km (36 mi) of marine coastal habitat and 547 km (340 miles) of USGS blue-line streams. Redwood Creek and its associated watersheds dominate the southern part of the park. The Klamath River is in the northern part of the park

and the Klamath River estuary is the only part of the drainage contained within the park boundary. Redwood Creek supports a number of salmonid species (i.e., cutthroat trout [*Oncorhynchus clarki*], coho salmon [*Oncorhynchus kisutch*], steelhead [*Oncorhynchus mykiss*], and chinook salmon [*Oncorhynchus tshawytscha*]) that are monitored on an annual basis. Green sturgeon (*Acipenser medirostris*), Klamath smallscale sucker (*Catostomus rimiculus*), and the tidewater goby (*Eucyclogobius newberryi*) are threatened and endangered fish species that also are monitored on an annual basis within the park. The park also supports a number of additional threatened and endangered species (see Appendix E of the KLMN Phase I Report).

The Redwood National Park Act as amended in 1978 gave the Secretary of the Interior the authority to reduce the impacts of upstream sedimentation and to rehabilitate areas that have been subject to timber harvesting in the past. Due to the nature of Franciscan rocks, the steepness of many slopes, the amount of precipitation, and the exposure of soil and bedrock from intensive logging, stream erosion and sedimentation have had and continue to have a profound impact on Redwoods lotic resources. The lower 40% of Redwood Creek is within the park and the upper 60% is on private land that has been logged. As a result of past land use and flood events, Redwood Creek is currently 303(d) listed under the Clean Water Act as sediment and temperature impaired.

Long-term geomorphic and hydrologic monitoring continues to be a priority on Redwood Creek and other creeks within Redwoods. Monitoring parameters include stream discharge, sediment transport, turbidity, temperature, channel stability, changes in pool and riffle distribution, pebble count and facies changes in streambed deposits. It may be difficult to determine the exact source of turbidity and sedimentation, but the primary sources appear to be the various impacts of logging roads inside and outside of the park. In cooperation with private landowners, park staff assists in surveying roads on private lands. Park staff also provides input to proposed Timber Harvest Plans in an attempt to minimize erosion. A project funded by the Environmental Protection Agency to evaluate the differences in the duration of turbidity for small streams with different disturbance levels was recently completed.

Road restoration has been a major undertaking at the park. This effort has restored many of the old logging roads and reduced landslide activity in those areas. However, most roads open to visitor traffic are gravel and subject to erosion. Adequate maintenance and upgrading of road drainage structures, culverts and other road features are concerns.

Redwoods coastal resources are largely unexamined and their condition is presently unknown. Redwoods and Humboldt State University are cooperatively inventorying coastline resources. The project is entitled “Assessment of the marine resources, including habitat type, vegetation types, and both algal, invertebrate and fish diversity along the park’s 36 miles of accessible coastline.”

Horizon Report

No report is presently available.

Fisheries Studies

- 1) Redwood Creek:
 - a. Invertebrate drift and juvenile salmonid habitat of the Redwood Creek watershed, 1981
 - b. Downstream migration, growth and condition of juvenile fall chinook salmon in Redwood Creek, Humboldt County, California, 1985
 - c. Juvenile salmonid habitat of the Redwood Creek basin, Humboldt County, California, 1988
 - d. Fish food habits and their interrelationships in lower Redwood Creek, Humboldt County, California, 1987
 - e. Fish food habits in the Redwood Creek estuary, 1990
 - f. Redwood Creek basin coho salmon (*Oncorhynchus kisutch*) summary reports, 1994
 - g. Redwood Creek basin fisheries summary, 1980-1994
 - h. Redwood Creek basin spawning and carcass surveys and annual reports: 1991-1992, 1993-1994, 1996-1997, 1997-1998, 2000-2001, 2002-2003
 - i. Redwood Creek estuary flood history, sedimentation and implications for aquatic habitat, 1983
 - j. Redwood Creek estuary monitoring and management: 1990, 1993, 1997-1999, 2002, 2003
 - k. Redwood Creek fish and amphibian distribution data [collection].
 - l. Redwood Creek summer steelhead trout survey: 1991, 1992, 1998, 1999, 2002
- 2) Prairie Creek
 - a. Effects of fine sediment on salmonid redds in Prairie Creek, a tributary of Redwood Creek, Humboldt County, California, 1991
 - b. Smolt production from Prairie Creek Hatchery juvenile coho reared in an Arcata wastewater-seawater pond, October 1992-May 1993
 - c. Prairie Creek salmon restoration, 1992-1993
 - d. Anadromous salmonid escapement and downstream migration studies in Prairie Creek, California, 1995-1996
 - e. Prairie Creek salmon redd composition, escapement and migration studies, Humboldt County, California, 1996-1997
 - f. Effects of sediments from the Redwood National Park bypass project (CALTRANS) on anadromous salmonids in Prairie Creek State Park, 1995-1998
 - g. Effects of sedimentation on incubating coho salmon, (*Oncorhynchus kisutch*) in Prairie Creek, California, 1998
 - h. Prairie Creek: Survival, growth and movement of juvenile coho salmon (*Oncorhynchus kisutch*) over-wintering in alcoves, backwaters, and main channel pools, 2001
 - i. Abundance and survival rates of juvenile coho salmon (*Oncorhynchus kisutch*) in Prairie Creek, 2002
- 3) Klamath River
 - a. Klamath River chinook salmon: use of radio telemetry to study adult upriver migration, 1982
 - b. Klamath River estuary: utilization by juvenile chinook salmon (*Oncorhynchus tshawytscha*), 1986
 - c. Assessment of fish habitat types within the Klamath River estuary: annual performance report, 1992

- d. Assessing the effects of moderately elevated fine sediment levels on stream fish assemblages, 2000
- 4) Coyote Creek Spring Pond brook trout removal, 1999, 2001, 2002
- 5) Fish habitat inventory for lower Lost Man Creek, 1990
- 6) Habitat utilization by 1987 and 1988 cohorts of chinook salmon from emergence to out-migration in Hurdygurdy Creek, California
- 7) Mill Creek monitoring program: juvenile salmonid monitoring on the east and west branches of Mill Creek, 1994
- 8) Smith River adult fish survey, 1997
- 9) Hoopa Valley Indian Reservation inventory of reservation waters, fish rearing feasibility study and a review of the history and status of anadromous fishery resources of the Klamath River Basin, 1979
- 10) Effects of large organic debris on channel morphology and process, and anadromous fish habitat in steep, montane coastal redwood environments, 1980
- 11) Large organic debris and anadromous fish habitat in the coastal redwood environment: the hydrologic system, 1983
- 12) Fish distribution survey reports: FY2000, FY2001, FY2002
- 13) Spawning survey results, 1983-1990
- 14) Tidewater goby surveys and reports: 1997, 1998, 2002

Beneficial Water Uses

Table 10 shows the beneficial uses of water in Redwoods as identified by the North Coast Regional Water Quality Control Board (NCRWQCB).

Table 10. Beneficial uses of water within Redwood National and State Parks (NCRWQCB).

Acronym	Definition
AGR	Agricultural Supply
COLD	Cold Freshwater Habitat
COMM	Commercial and Sport fishing
EST	Estuarine Habitat
FRSH	Freshwater Replenishment
GWR	Groundwater recharge
IND	Industrial Service Supply
MAR	Marine Habitat
MIGR	Fish Migration
MUN	Municipal Supply
NAV	Navigation
PROC	Industrial Process Supply
RARE	Preservation of Rare and Endangered Species
REC 1	Contact Water Recreation
REC2	Non-contact Water Recreation
SHELL	Shellfish Harvesting
SPWN	Fish Spawning
WARM	Warm freshwater habitat
WILD	Wildlife Habitat

Wildlife Monitoring

- 1) Redwood Creek estuary salmonid monitoring for adult spawning and juveniles
- 2) Redwood Creek monitoring for deformed amphibians
- 3) Marine mammal carcass monitoring (ongoing)
- 4) Marbled murrelet, snowy plover and brown pelican monitoring

Water Quality Concerns

- 1) Freshwater
 - A) Effects of adjacent land use, in particular, logging on water quality
 - B) Water quality issues related to Clean Water Act (CWA) Section 303(d) impaired stream segments (i.e., Redwood Creek sedimentation/siltation and temperature, and Klamath River nutrients and temperature)
 - C) Water quality of Redwood Creek watershed related to sediment transport trends, water and suspended-sediment discharge, and water chemistry and aquatic biology
 - D) Impacts of recreational catch and release fishing on threatened salmonid species

Note: a full discussion of the CWA Section 303(d) listing and Total Maximum Daily Load (TMDL) program process can be found at the following EPA web site:

<http://www.epa.gov/owow/tmdl/>

2) Marine

- A) Completion of coastal and intertidal inventories including assessments of human impacts, invasive species, offshore sediment budget and potential hazards such as oil spills
- B) Compliance of near- and offshore water quality with State Water Quality Control Board standards
- C) The impact of river flow output (e.g., Klamath River plume) on coastal habitat, productivity, and water chemistry
- D) The potential presence of contaminants in the near- and offshore waters
- E) Lack of complete inventories from most marine habitats (Table 11)

Table 11. Marine inventory needs at Redwood National and State Parks.

PELAGIC	SUBTIDAL	INTERTIDAL	ESTUARY
Fish Marine Mammals Marine Birds Marbled Murrelet Brown Pelicans	Habitat Typing (Rock, Sand, Kelp) 36 miles of coastline Bathymetry Near Shore Currents & Wave Action Fish Distribution	Habitat Typing (Rock, Sand) 36 miles of coastline Invertebrates, Plants, Fish (Distribution and Amount) Large Woody Debris Visitor Use (Areas used)	Substrate Typing (Rock, Sand, Mud) Aquatic Plants Bathymetry

See Attachment I for RNSP watershed monitoring, water quality, and fisheries inventory, monitoring and research study references.

4.6 WHISKEYTOWN NATIONAL RECREATION AREA (WHIS)

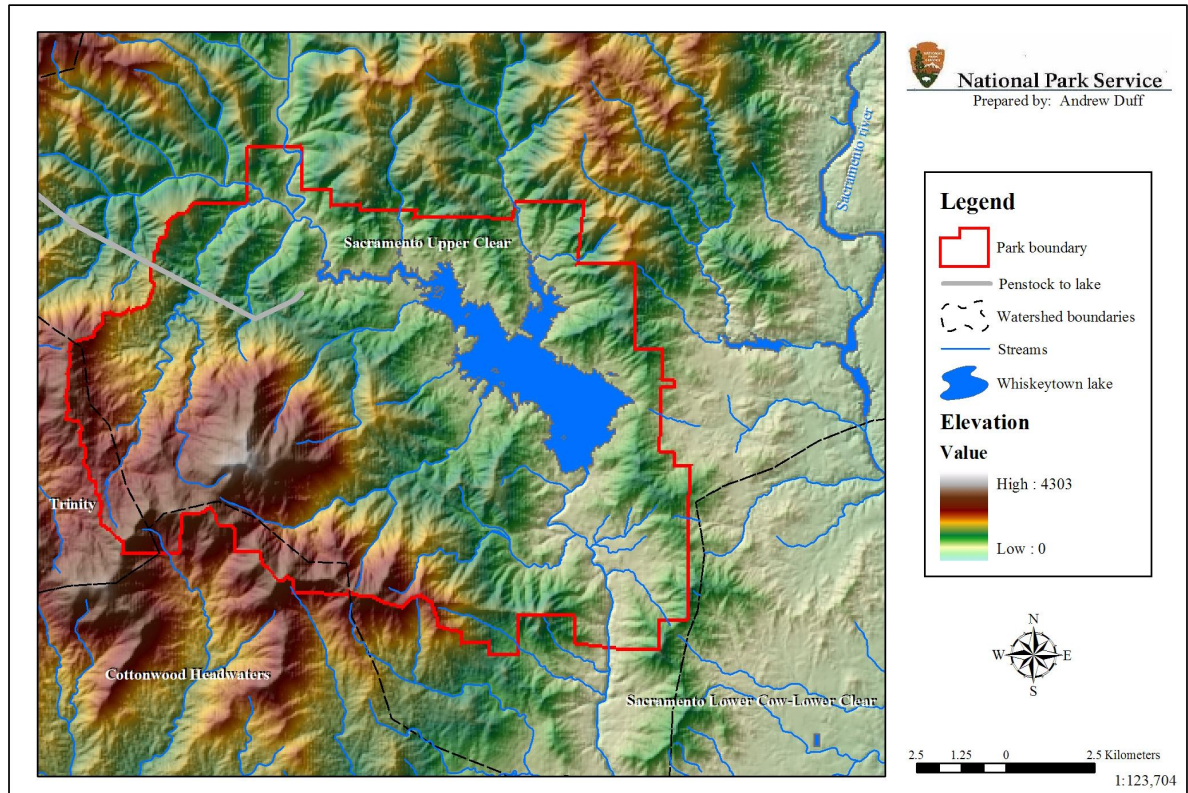


Figure 9. Aquatic resources and watershed boundaries of Whiskeytown National Recreation Area.

Whiskeytown National Recreation Area (Figure 9) was authorized by Congress on November 8, 1965 (“...to provide...for the public outdoor recreation use and enjoyment of Whiskeytown reservoir and surrounding lands...”) and established on October 21, 1972. Whiskeytown is the only unit of the Whiskeytown-Shasta-Trinity National Recreation Area administered by the National Park Service; the Shasta and Trinity units are administered by the US Forest Service. The Whiskeytown unit (17,198 hectares; 42,497 acres) is located at the northern end of the Sacramento Valley, eight miles west of Redding, California, and Whiskeytown Lake is surrounded by shrubland, oak woodland, and montane forests.

Whiskeytown Lake was created by the Bureau of Reclamation in 1962, when the Clair A. Hill Whiskeytown Dam, blocking Clear Creek, was completed. The reservoir contains 3,220 surface acres (240,000-acre feet) of water at full capacity, and serves as the domestic water supply for the California cities of Redding, Old Shasta, Centerville, Keswick, and Happy Valley. It is also one of several reservoirs that store water for the Central Valley Project. Seven major streams empty directly into the reservoir: Clear, Mill, Brandy, Crystal, Boulder, Willow and Whiskey Creeks. Intermittent streams abound throughout the park unit, and many springs are found at higher elevations.

Whiskeytown has approximately 850,000 visitors annually, with the majority visitation concentrated in and around the reservoir. Sailing, skiing, fishing, swimming, and kayaking are popular recreational activities. There are two permanent marinas, one additional boat launch site, three designated campgrounds, two developed day use beaches, and numerous smaller beaches along the reservoir. The reservoir is stocked annually with both native and non-native fishes by the California Department of Fish and Game.

Horizon Report

Surface water quality data for Whiskeytown were collected by eight agencies (i.e., California Department of Fish and Game, California Department of Health Services, California Department of Water Resources, California Water Resources Control Board, National Park Service [WHIS and Water Resources Division], UC Davis, USDI Bureau of Reclamation, and US Geological Survey), between 1962-1998 (NPS-WRD, 2000). Numerous sites throughout the reservoir (Whiskeytown Lake), as well as 12 streams, 4 springs, and 2 mines (NPS-WRD 2000, pages 45-47) were sampled during this time period. A total of 128 stations were sampled and all but 17 stations were either sampled once or intensively for a single-year (NPS-WRD 2000). The 17 relatively long-term stations were located at numerous sites around the reservoir, or on Clear and Willow Creeks. Many of the 203 parameters assessed between 1962-1998 (NPS-WRD 2000, pages 48-51) were potential indicators of water quality problems associated with (1) human recreational activities and waste disposal, and (2) point source pollution due to past mining activities and clandestine-illegal marijuana cultivation. These water quality parameters continue to be monitored (1999-present). A Horizon Report for WHIS is available at: (http://nrdata.nps.gov/WHIS/nrdata/water/baseline_wq/docs/WHISWQAA.pdf).

Additional Activities

Water quality related activities at Whiskeytown also include four recent projects not covered by the NPS-WRD (2000) Report. In 1996, Whiskeytown began a cooperative watershed restoration partnership with Shasta College and Salix Applied Earthcare, a natural resource consulting firm, both located in Redding, California. The cooperative project was titled “Watershed Restoration and Logging Road Removal Project in the Paige Bar Demonstration Watershed” and was designed, in part, to demonstrate the capacity for restoring watershed water quality and fish habitat. The project received the National Park Foundation Environmental Conservation Award in 1999. USGS Project CA598 was designed to identify and characterize contaminant “hot spots” in Whiskeytown due to past mining activities, and to examine the potential adverse effects of mercury and other heavy metals on aquatic biota. This project, begun in April, 2002, examined 15 sites throughout Whiskeytown and concluded in September, 2004 (Hothem *et al.* 2002-2004). In February, 2004, USGS Project 9VL22 was initiated to assess the aquatic biology, habitat, and water quality conditions of the major Whiskeytown watersheds (May & Brown 2004-2006). This project will conclude in September, 2006. In 2002, USGS personnel surveyed and inventoried the presence of amphibians and turtles in 12 Whiskeytown streams and one pond. Amphibians and turtles were again surveyed and inventoried in 2004, in nine Whiskeytown streams and one pond, and in five arms of the reservoir. Fisheries activities in Clear Creek at Whiskeytown have been associated with a larger

effort concerning the restoration of anadromous fish in the Sacramento River drainage area (NMFS 1997, USFWS 2001, CDFG 2002).

Water Quality Concerns

- 1) ArcGIS feature datasets of aquatic resources within the park unit boundary have yet to be completed
- 2) Disturbance and contamination of stream habitats due to clandestine-illegal marijuana cultivation
- 3) Introduction of nonnative fish and wildlife (particularly bullfrogs) species
- 4) Spread of exotic plant species within Whiskeytown Lake

See Attachment I for WHIS water quality and fisheries inventory, monitoring and research study references.

4.0 SUMMARY OF PAST ACCOMPLISHMENTS AND FUTURE INVENTORY, MONITORING AND RESEARCH NEEDS IN KLAMATH NETWORK PARK UNITS

Klamath Network park units have completed, at minimum, partial inventories of park-specific aquatic resources and short-term water quality sampling and monitoring of these resources:

1. Crater Lake National Park has focused primarily on monitoring the water quality of Crater Lake. A long-term lake monitoring program has been active since 1983. Less comprehensive water quality inventories have been completed for ponds/lakes and streams located outside of the Mt. Mazama caldera. A Sun Creek bull trout restoration project and a survey of amphibians in the Whitehorse Ponds have also been initiated and/or completed.
2. Surveys of Lassen Volcanic National Park ponds/lakes, wetlands and streams have focused primarily on documenting baseline ecological condition and developing management and research alternatives for these resources. The status of aquatic invertebrates, native amphibians and nonnative fish in Lassen lentic habitats has also been documented. Hydrothermal/geothermal resources have been continuously monitored since 1981, focusing on water quality characteristics, potential impacts of these resources on visitors, and potential visitor impacts on the resources.
3. Aquatic resource inventory, monitoring and research activities at Lava Beds National Monument have included surveys of ice cave baseline water quality, monitoring of ice depth, and monitoring of groundwater depth and availability. Lava Beds is also concerned about the potential effects of adjacent land use practices (e.g., agriculture and geothermal exploration and development) on park unit aquatic resources.
4. Oregon Caves National Monument has focused on documenting the baseline water quality of pools, springs and streams in or near the park unit cave system. The physical characteristics and magnitude of potential direct human impacts on park unit aquatic resources also have been inventoried and continue to be monitored.
5. Redwood National and State Parks has monitored stream surface flow and sediment transport and deposition since 1972. The focus of these activities has been the long-term geomorphic and hydrologic monitoring of park unit freshwater lotic systems with emphasis on: (1) impacts due to human-related activities such as logging and road building; (2) water quality issues related to Clean Water Act section 303(d) impaired stream segments (i.e., Redwood Creek and Klamath River); (3) the impact of human-related activities on anadromous salmonids in park unit streams; and (4) the status of native amphibians in park unit lotic habitats. The status and trends of Redwoods marine ecosystems have been minimally examined. However, coastal and intertidal inventories are underway that are designed to assess, in part, human and invasive species impacts, offshore sediment budget, and potential impacts of perturbations such as oil spills to marine ecosystems.
6. Aquatic resource inventory, monitoring and research activities at Whiskeytown National Recreation Area have focused on the water quality of Whiskeytown Lake and its inlet and outlet streams. Water quality sampling has emphasized documentation of potential resource

perturbation due to: (1) human recreation activities and waste disposal; (2) point source pollution due to past mining activities and practices; (3) point source pollution due to clandestine-illegal marijuana cultivation; and (4) impacts due to logging and road building. Additional projects have been initiated or completed to: (1) assess the baseline water quality, biology and habitat conditions of the major Whiskeytown watersheds; (2) demonstrate the potential for watershed restoration; (3) determine the status of amphibians and turtles; and (4) survey the status of and potentially restore anadromous salmonids in Clear Creek.

The descriptions of past inventory, monitoring and research activities in each park unit highlight future network-wide inventory, monitoring and research needs. It is clear that all aquatic resources in each park unit have not been fully inventoried nor have present baseline water quality conditions been fully determined. These baseline conditions should include documentation of the physical, chemical and biological characteristics of each water resource-type. Once these present baseline conditions are determined, appropriate resource sampling designs can then be used to more effectively monitor for potential resource-specific changes. The need for consistent freshwater inventory and monitoring techniques across park units has been identified as an important part of any network-wide program. Consistent sampling design and sample collection will facilitate the comparison and interpretation of water quality monitoring results among park units. Additional important inventory and monitoring activities should include: (1) development of a general monitoring program for Redwoods marine ecosystems; (2) inventories of wetland biota; (3) salmonid fisheries monitoring; (4) amphibian monitoring; and (5) benthic macroinvertebrate studies.

5.0 WATER QUALITY MONITORING AND RESEARCH PROGRAMS OF ALLIED AGENCIES RELEVANT TO KLAMATH NETWORK PARK UNITS

This section describes past and ongoing research or monitoring programs in the Klamath Network region. Many of these programs could provide funding, protocols, or partnership opportunities for the Klamath Network as it develops its water quality monitoring program.

A. US Environmental Protection Agency (USEPA), Environmental Monitoring and Assessment Program (EMAP) - Surface Waters - Western Pilot Study, USEPA (with collaborators). Project Dates: 2000 – 2005: The Western Pilot study is the Surface Waters component of the USEPA Western Geographic Study through the EMAP Program. The program goal is to answer questions about the importance of stressors and the extent of their effects on ecological condition of wadeable streams; the objective is to develop monitoring tools to estimate the ecological condition of surface waters across the Western US. Project methodology includes sampling of water chemistry, stream discharge, periphyton, sediment, benthic macroinvertebrates, fish, and physical habitat characteristics. Contact: David Peck, USEPA, Corvallis, OR. Phone: 541-754-4426, E-mail: peck.david@epa.gov.

B. US Environmental Protection Agency (USEPA), Environmental Monitoring and Assessment Program (EMAP) – National Coastal Assessment, USEPA (with

collaborators). Project Dates: 1990 – 2003: The USEPA National Coastal Assessment has conducted estuarine monitoring in all 23 coastal States and Puerto Rico (accounting for 99.8% of estuarine acreage in the continental US and Puerto Rico). Data from several regional and national programs conducted by NOAA, USGS and the USFWS are included in the assessment of coastal condition. The West Coast of the US was assessed in 1999 and 2000, and the assessment was extended in 2003 to cover the continental shelf. Marine biota (plankton, benthos, and fish) and environmental stressors (water quality, sediment quality, tissue bioaccumulation) were sampled. The first and second Coastal Assessment Reports can be accessed using the following website link:

<http://www.epa.gov/owow/oceans/nccr2/index.html>. Contact: J. Kevin Summers, US EPA. Phone: 850-934-9201, summers.kevin@epamail.epa.gov.

- C. National Oceanic and Atmospheric Administration (NOAA), with the Western Regional Climate Center (Desert Research Institute). Climate Reference Network. Project Dates: implemented in 2004:** The Climate Reference Network is a network of climate stations being established, with the help of the Western Regional Climate Center, as part of a NOAA initiative. The goal of this project is to monitor long-term precipitation and temperature observations to investigate present and future climate change. If fully implemented, the network will have about 250 sampling stations nationwide. Many of these stations are being established in national parks. Contact: John Jensen, Program Manager, NOAA. Phone: 828-271-4475, E-mail: John.A.Jensen@noaa.gov.

- D. US Geological Survey (USGS), Amphibian Research and Monitoring Initiative (ARMI), with NPS, FWS, BLM. Project Dates: 2000 – ongoing:** In response to growing awareness of amphibian declines and malformations, the USGS ARMI program was initiated by the United States Congress in 2000 to monitor trends in amphibian populations on Department of Interior (DOI) lands; and to research the cause of amphibian declines. While intensive monitoring will be focused on DOI lands, ARMI will also provide a framework for other agencies outside of DOI lands for incorporating amphibian monitoring data. Partnerships with other DOI agencies include a nationwide Fish and Wildlife Service survey for contaminants that may induce malformations in amphibians on 48 National Wildlife Refuges in 31 states. Contact: Mike Adams, Wildlife Biologist, USGS Forest and Rangeland Ecosystem Science Center (FRESC) Corvallis, OR. Phone: 541-758-8857, E-mail: Michael_adams@usgs.gov.

- E. US Geological Survey (USGS), National Water Quality Assessment Program (NAWQA) – Sacramento River Basin Study. Project Dates: 1994 – 1998:** The Sacramento River water quality assessment, covering the river’s nearly 75,000 sq km (27,000 sq mi) drainage basin, is the largest within the State of California. The study was divided into 5 physiographic provinces: the Sacramento Valley, the Sierra Nevada, the Coast Ranges, the Cascade Range and the Modoc Plateau. The major use of Sacramento River water is for agriculture (58%), environmental management (32%), urban land use (6%), and other (4%). A suite of water quality parameters were measured including temperature, pH, dissolved oxygen, specific conductance, major cations and anions, metals, suspended sediment, bed sediment, discharge, and fish tissue samples for contaminants. The major issues within the basin are elevated concentrations of trace metals, especially from abandoned mines (WHIS); pesticide contamination of surface water and potential contamination of ground water (LAVE, LAVO, WHIS); nitrate contamination of ground water (LAVE, LAVO, WHIS); and urban runoff and volatile-organic-chemical contamination. Contact: Joseph Domagalski, USGS, Sacramento, CA. Phone: 916-278-3077, E-mail: joed@usgs.gov.
- F. US Geological Survey (USGS), National Stream-gaging Program (NSP), with Federal, State, and Local agencies. Project Dates: variable and ongoing:** The USGS has been collecting streamflow information since 1887. The NSP, which partners with many agencies, monitors flows on major and minor streams at nearly 7,000 stations throughout the US. Streamflow gaging stations provide data that can be used for planning and operating water resources projects, flood warning and control operations, and long term background information about changes in streamflow in response to climate and changes in land use. Contact: Mike Norris, USGS, Phone: 703-648-5304, E-mail: mnnorris@usgs.gov.
- G. US Geological Survey (USGS), Forest and Rangeland Ecosystem Science Center (FRESC), Project: Development of monitoring protocols for mountain lakes and ponds at North Cascades National Park Service Complex:** This project began in 2001 with the purpose of developing a sampling protocol for mountain ponds and lakes. The NPS North Coast and Cascades Network is the project partner and this protocol has been developed for all park units in this network. The protocol also has been written as a document that can be used by any agency, institution or group (e.g., KLMN) interested in sampling montane lentic ecosystems. The protocol is in press and will be published as stand-alone chapter of a USGS Techniques and Methods document (Techniques and Methods 2-A2). Contact: Robert Hoffman, USGS FRESC (Phone: 541-750-1013, E-mail: robert_hoffman@usgs.gov) and Gary Larson, USGS FRESC (Phone: 541-750-1032, E-mail: gary_l_larson@usgs.gov).
- H. US Forest Service (USFS) and Bureau of Land Management (BLM) Watershed Analyses. Approximately 1995 – present:** Watershed analyses have been conducted by the USFS National Forests and BLM Districts throughout the KLMN region. These analyses are part of the process of implementing ecosystem management as directed by the Northwest Forest Plan. USFS National Forests include: Fremont-Winema, Klamath, Rogue River-Siskiyou, Shasta-Trinity, and Six Rivers; BLM Districts include: Coos Bay, Lakeview, and Medford. Over 76 watersheds have been analyzed since 1995. Each

watershed analysis includes the characterization of current and reference conditions in 14 basic categories: (1) human uses; (2) roads; (3) climate; (4) erosion processes; (5) soil productivity; (6) vegetation density and vigor; (7) plant species and habitats; (8) fire; (9) terrestrial wildlife species and habitats; (10) hydrology; (11) stream channel; (12) water quality; (13) riparian areas; and (14) aquatic wildlife species and habitats. Many of the watershed analyses reports are available at each USFS National Forest and BLM District internet web site.

- I. Northwestern California/Klamath Bioregion Environment Information Sources:** This is an internet website hosted by the Humboldt State University Library at <http://library.humboldt.edu/~rls/NorCalEnv.htm#water>. The site provides clickable links to environmental data made available by various entities throughout the Klamath Region. Water resources/water quality site links include: (1) California Data Exchange Center; (2) California Nevada River Forecast Center; (3) EPA – Established TMDLs; (4) Hydro-Climatic Data Network; (6) Klamath Resource Information System (KRIS) Web Bibliography; (7) National Water Information System (NWISWeb) Data for California (USGS); (8) Regional Assessment of Stream Temperatures Across Northern California and Their Relationship to Various Landscape-Level and Site-Specific Attributes; (9) Surf Your Watershed; (10) Water Data Library (California Department of Water Resources); and (11) Water Resources Data: California (USGS).
- J. California Department of Fish and Game Stream Bioassessment Procedure:** The mission of the California Department of Fish and Game's Aquatic Bioassessment Laboratory is to use biology in the management and assessment of California water quality. This procedure utilizes aquatic invertebrates for the rapid bioassessment of stream water quality. Background information and the bioassessment procedure are available at <http://www.dfg.ca.gov/cabw/cabwhome.html>.
- K. California North Coast Watershed Assessment Program:** The development of this interagency program was initiated in 1999 by the California Resources Agency and the California Environmental Protection Agency. The California agencies participating in this program are (1) Department of Fish and Game, (2) Department of Forestry and Fire Protection, (3) Division of Mines and Geology, (4) Department of Water Resources, and (5) North Coast Water Quality Control Board. The program purpose is "to develop consistent, scientifically credible information to guide landowners, agencies, watershed groups, and other stakeholders in their efforts to improve watershed and fisheries conditions." Detailed information about this program is available at <http://www.ncwatershed.ca.gov>.

6.0 NETWORK-WIDE SCOPING AND ISSUES IDENTIFICATION FOR VITAL SIGNS MONITORING

6.0.1 Purpose, Need and Approach

The Klamath Network is in the process of developing a long-term water quality monitoring plan for its park units. Development of the water quality monitoring plan follows the guidance given in a May 2002 Memorandum to National Park Service Regional I&M Coordinators. The memo outlines the three-phase approach for developing a monitoring plan. Phase 1 of the network's water resources and water quality assessment provides introductory and background resource and quality information for each park unit in the network. Phase 2 provides a more in-depth review of the aquatic resources and past water quality inventory, monitoring, and research activities in each park unit; and discusses the process of identifying and prioritizing specific "vital signs indicators" (i.e., indicators of ecosystem health) to be monitored as part of a long-term water quality monitoring program. Phase 3 details the steps required to implement an integrated long-term monitoring program including development of: (1) monitoring objectives for each priority vital sign; (2) sampling protocols and sampling designs; and (3) a plan for data management, analysis and reporting.

Water quality issues were identified, during the Klamath Network's general ecosystems vital signs scoping process, as an important element of the overall health of the network's diverse ecosystems. The network also identified the need for a working water quality subgroup of the Science Advisory Committee (SAC). The subgroup was given the task of making recommendations concerning water quality issues and implementing tasks that the committee considered significant. Their first assignment was to recommend additional Phase I basic water quality inventories for three network park units (LAVO, LABE, and ORCA) based upon a preliminary evaluation of existing water quality information and its currency by the National Park Service Water Resources Division. The second task for the subgroup was to develop and write a Phase I Water Quality Report. The network decided, based upon existing network expertise and available time, to produce the Phase I Report in-house, with technical assistance from the park units. The network did not identify the need to hold a separate water quality scoping and/or vital signs meeting to gather park-specific water quality information. Rather, the identification of water quality vital signs was incorporated as one of the tasks of the Aquatic Group participating in the network's third Vital Signs Workshop held May 4-6, 2004. The purpose of this workshop was to identify Level 1 and Level 2 Categories of the National Vital Signs Framework and to provide examples of vital signs and their measurement associated with these categories. A meeting focusing specifically on identifying water quality vital signs for each network park unit was completed on December 1, 2004.

6.0.2 Vital Signs Scoping

The Klamath Network began its vital signs monitoring scoping process in 1998. A detailed account of the process and key findings were reported in Sarr *et al.* (2004). Initial park-specific Vital Signs Workshops were held between 1998 and 2003 to begin to identify stressors that potentially impact park unit ecosystems. These workshops were followed in 2004 by three network-wide workshops: (1) Marine (January 27-28); (2) Geology/Soils (March 1-4); and (3)

Level 1 and 2 Categories of the National Vital Signs Framework (May 4-6). The purpose of these workshops was to more specifically identify monitoring questions and vital signs associated with specific ecosystems and categories (see Sarr *et al.* 2004, Appendix G, pages 4-17 including Table 1, pages 16-17, for a complete list of National Vital Signs Framework Categories). Detailed results of the May 4-6 workshop specific to Klamath Network park units can be reviewed in Sarr *et al.* 2004, Appendix G, Tables 2-7, pages 18-46.

General Water Quality Issues Identified during the May 2004 Scoping Process

The dominant theme during the initial identification of network-wide water quality issues was aquatic ecosystem health. The ability to (1) document improvement (or lack thereof) in the water quality of Clean Water Act section 303(d) listed streams, and (2) the ability of park unit managers to document progress toward achieving GPRA goal 1.a4 (i.e., that park units have unimpaired water quality), underscored the importance of identifying a suite of vital signs useful for effective water quality assessment. The need to fully inventory aquatic resources and document baseline and reference water quality conditions also were identified as important objectives in the development of a vital signs-based long term water quality monitoring program. The vital signs initially identified included:

- **Watershed budgets:** A watershed budget is one method for monitoring water quality. It is an accounting of the inputs and outputs of water, nutrients, sediments, and chemicals passing through a particular watershed; and budgets vary considerably among watersheds. Typical monitored parameters include the concentration of major ions and isotopes, stream flow, groundwater hydrology, and continuous water temperature.
- **Continuous water temperature measurement:** Water temperature can be a useful indicator of the status and trends of aquatic ecosystems. Change in water temperature can be indicative of ecosystem impact due to climate change or other anthropogenic-derived perturbations. However, the intermittent monitoring of temperature can be problematic due to the significant temporal variation of temperature. Use of continuous recording devices is a preferred means of eliminating time-associated sampling variation.
- **Groundwater quantity and quality:** This vital sign refers to the monitoring of groundwater level and chemistry (including contamination). Monitored parameters include groundwater level and volume, pH, temperature, conductivity, trace organic compounds and metals. Samples for analysis are obtained through purging and sampling groundwater wells.
- **Reservoir elevation.** Lakes that are hydrologically managed (i.e., water impounded by a dam) will have fluctuating water levels that can potentially affect lake food webs and ecosystem function. Therefore, changes in water surface elevation and storage capacity, as well as water inflow and discharge should be part of the long-term monitoring of reservoirs.
- **River invertebrate assemblages.** The composition of an invertebrate assemblage can be a useful indicator of water quality; and may change in response to the presence of exotic species, as well as changes in sedimentation rate, nutrient loading, composition of

predator population, and climate. Two methods can be used to identify and document change: (1) comparing the species of a measured assemblage structure with species that may be indicative of a particular water quality condition (e.g., Stribling *et al.* 1998), and (2) using multivariate analysis to compare a predicted invertebrate assemblage structure to a measured structure (e.g., Hawkins *et al.* 2001, Lewis *et al.* 2001).

- **Distribution and hydrology of springs and seeps:** This vital sign includes documenting the location, volume, duration, and seasonality of flow of springs and seeps. Parameters are quantified by calculating physical/geometric metrics (i.e., water depth [maximum, minimum, average]; site length, and width) and discharge (flow quantity, duration, and peak) at each spring or seep.
- **Stream flow/discharge:** Stream flow is the measure of the flow of water in a stream at a specific time relative to (1) watershed routing mechanisms and water quality, (2) watershed land-use activities, and (3) natural and point-source discharges within the watershed. Stream discharge (Q) is defined as the unit volume of water passing a given point on a stream or river over a given time. It is typically expressed in cubic feet per second (cfs) or cubic meters per second (cms) and is based on the equation: $Q = A \cdot V$, where A is the cross-sectional area of the stream at the measurement point and V is the average velocity of water at that point.
- **Water chemistry:** Information from monitoring water chemistry is used to evaluate water quality with respect to stressors such as atmospheric deposition, nutrient enrichment, and inorganic contaminants. The following parameters and ions are usually monitored: alkalinity, ammonia, bicarbonate, carbonate, calcium, chloride, fluoride, trace metals, nitrate, pH, potassium, silica, sodium, sulfate, total dissolved solids, total suspended solids, total nitrogen, and total phosphorous. In streams, concurrent discharge measurements allow data to be presented as mass flow (e.g., g/hr).
- **Algal species composition and biomass:** Algal species composition refers to the kinds of species present in a body of water. Algal biomass refers to the combined mass of the species. Certain species can indicate changes in water column nutrient input or water temperature. Algal composition is measured by examining algal assemblages, whereas algal biomass can be measured using chlorophyll *a* concentrations or Secchi disk water clarity measurements.
- ***Escherichia coli* (E. coli):** The presence of *E. coli* in a water sample is an indicator of fecal contamination. This bacterium can cause gastrointestinal distress and illness in humans and can be contracted by drinking contaminated water or by swimmers recreating in contaminated swimming areas. Determination of *E. coli* contamination is based on the density of the indicator organism in a water sample. The EPA requires that the concentration of *E. coli* in a water sample be no more than a geometric mean of 126 *E. coli* per 100 ml of fresh water, or 260 *E. coli* per 100 ml for any single sample.
- **Exotic aquatic species community structure and composition:** Introduced exotic aquatic species can affect the ecosystem dynamics of a water body and negatively impact naturally occurring native biota in affected systems. Monitoring the distribution (geographical location), abundance (number at each sampling location), and spread of exotic species can help managers understand the potential environmental consequences of these organisms. Introduced exotic species of concern include fish (e.g., kokanee

[*Oncorhynchus nerka*] in Crater Lake and brook trout [*Salvelinus fontinalis*] in western montane lakes and streams), as well as invertebrates (e.g., the New Zealand mud snail [*Potamopyrgus antipodarum*]).

- **Native aquatic species community structure, composition, stability and genetic integrity:** This vital sign is associated with the overall health of native biota in water bodies of interest. Monitored parameters include the determination of the condition of native biotic communities based on metrics of species richness, composition, and trophic status, relative abundance, presence/absence, and genetics.
- **Atmospheric deposition (wet and dry) of nitrogen, sulfur, and all major anions and cations:** Atmospheric deposition is the process whereby air-borne particles, aerosols, and gases move from the atmosphere to the earth's surface. This vital sign is quantified by measuring snow-pack chemistry and direct measurements of wet (NADP/NTN) and dry (CASTNet) deposition. Fire (e.g., wildfire or controlled burns) also is a source of atmospheric deposition of pollutants, and can reduce visibility in KLMN park units.
- **Basic climatological measurements:** Monitoring parameters associated with this vital sign will help park unit managers identify potential climate change. Basic climatological measurements include: temperature (maximum, minimum, and average), precipitation, relative humidity, wind velocity and pattern, surface pressure, as well as snow cover, depth and water equivalent. The following are recommended standard metrics for these climatological variables: air temperature (°C), surface wind (m/s), and atmospheric humidity/water vapor (as percent, mixing ratio in g H₂O/kg-air, or concentration in g H₂O/m³), surface pressure (hectopascals [hPa] or millibars [mb]), snow cover and depth (water equivalent per km² and/or percent of area for cover and mm/cm for depth).
- **Stream sediment transport.** Sediment data, both suspended and bedload, are required for the evaluation of stream sediment yield with respect to (1) background environmental conditions (geology, soils, climate, runoff, topography, ground cover, and size of drainage area), (2) historic and current land use, and (3) erosion and deposition in channel systems. Additionally, understanding the temporal distribution of sediment concentration, size characteristics, and transport rates is crucial to the management of in-stream aquatic communities and riparian ecosystems. Standardized sediment sampling methods and the frequency of collection will be dictated by the hydrologic and sediment characteristics of the water body to be sampled, the required accuracy of the data, the funds available, and the proposed use of the collected data.

Table of Monitoring Questions and Vital Signs Identified during the May 2004 Scoping Process

The Level 1 category, Water, was divided into three Level 2 subcategories (i.e., hydrology, subterranean, and water quality) during the May 2004 vital signs scoping meeting. Monitoring questions were developed and vital signs identified for each subcategory and are presented in Table 12. Full details of the results of the May 2004 meeting are available in Appendix G of Sarr *et al.* (2004).

Table 12. Monitoring questions and potential vital signs for water, a National Framework Level 1 Category (SAC = Science Advisory Committee).

Subcategories (Level 2)	Monitoring Question	Vital Sign (Klamath)	Question Identified by	Comments
Hydrology	What is the effusion rate of groundwater into the surface environment? (geothermal)?	Groundwater dynamics (discharge)	Process	
	What types of groundwater changes are occurring in network park units?	Aquifers (depth volume variability)	Aquatic	
		Hyporheic zones	Aquatic	
	What is happening with the hydrological cycle?		Terrestrial	
	What are trends in soil moisture across vegetation habitats?	Evapotranspiration	Terrestrial	
	What is the status and what are the trends of hydrothermal output into aquatic system?	Water chemistry	Process	
	What impact does seepage have on groundwater quality?	Groundwater (discharge and composition)	SAC	
	What is the status and what are the trends of water flow (water supply) in network park units?	Water flow	SAC	
		Water supply	Process, Aquatic	
Subterranean	How are changes in water and ice quantity, rates, and quality affecting erosion, deposition, and biota?	Water Flow (quantity)	Cave, Aquatic	
		Distribution (Water/Ice Budget)	Cave, Aquatic	
		Crustaceans and worms	Cave, Aquatic	
		Water Chemistry (quality)	Cave, Aquatic	

Subcategories (Level 2)	Monitoring Question	Vital Sign (Klamath)	Question Identified by	Comments
		Microorganisms	Cave	
Water Quality	What is the status and what are the trends of point source pollution inputs?	Pollutants (inorganic)	Process, Marine	
	What is the status and what are the trends of non-point source pollution inputs?	Pollutants (organic)	Marine	
		Water chemistry	Process, Aquatic	
		Nutrient levels	Whiskeytown	
	What is the status and what are the trends of watercraft emissions?	Hydrocarbon deposition	SAC	
	What is the status and what are the trends of aquatic biological communities?	Aquatic organisms	Aquatic	benthic algae, canopy cover, macroinvertebrates, freshwater mussels, substrate
		Water (physical)	Aquatic	
	When and how much water is occurring in ephemeral systems and can we detect a change over time?	Vernal pools	Terrestrial	
		Ephemeral streams	SAC	
		Littoral ponds (Crater Lake)	SAC	
		Seasonal wet meadows (LAVO))	SAC	
		Snow melt beds	SAC	
	Are the sizes and distributions of perennial water bodies (streams, lakes, snow fields, springs, wetlands) changing over time?	Distribution of water bodies	Aquatic	
	What is the extent of material, biological, and chemical pollution in the marine ecosystem?		Marine	

Subcategories (Level 2)	Monitoring Question	Vital Sign (Klamath)	Question Identified by	Comments
Water Quality	What is the status and what are the trends of marine trash (material trash)?	Seabirds	Marine	Percent of beached marine seabird carcasses with attached debris
	What is the status and what are the trends of marine mammals (?):	Marine mammals	Marine	percent of beached marine mammal carcasses with attached debris
	What are the impacts of terrestrial sources of intertidal pollution (?):			
	-oil	Oil Seabirds	Marine	Presence/absence of oiled beach marine seabird carcasses
		Marine mammals	Marine	Presence/absence of oiled beach marine mammal carcasses
	-river discharged pollution	Pollutants	Marine	Similar water quality testing as done by State Water Quality Control Board
	-salinity	Surface salinity	Marine	Annual and seasonal variations in open ocean and estuary

Subcategories (Level 2)	Monitoring Question	Vital Sign (Klamath)	Question Identified by	Comments
Water Quality	-turbidity/clarity	Turbidity	Marine, VSA	NTUs, light penetration in estuary, intertidal and subtidal zones, extent of turbid river plumes
	What is the status and what are the trends of sea surface and subsurface water temperature?	Sea surface and subsurface water temperature	Marine	Annual and seasonal variations of water samples in open ocean
	What is the status and what are the trends of dissolved oxygen in estuarine ecosystems?	Dissolved oxygen	RNSP, Marine	Annual and seasonal variations of water samples in estuary
	What are the effects of upstream management on estuaries (dams, flow regulation, water quality)?	Water temperature (estuary)	Marine	Annual and seasonal variations of water samples in estuary
		Chlorophyll a	Marine	Annual and seasonal variations of water samples in estuary
		Coliform bacteria	Marine	Annual and seasonal variations of water samples in estuary
		Herbicides associated with forestry application	Marine	Annual and seasonal variations of water samples in estuary
	What are the effects of upstream management on estuaries (land use)?	Dissolved oxygen (estuary)	Marine	Annual and seasonal variations in estuary

Priority Aquatic Resource Monitoring Questions

Two of the 10 most important network-wide vital signs monitoring questions identified at a Klamath Network meeting in Redding, California, April 27-28, 2005, were aquatic resource-focused. The top 10 monitoring questions (out of 172 monitoring questions and associated vital signs) were selected based on the total rating assigned to them by the individuals who participated in the Klamath Network vital signs/monitoring question rating process.

The two aquatic resources monitoring questions are:

- 1) What is the status and what are the trends of surface waters and pollutants, and
- 2) What is the status and what are the trends in structure, function and composition of locally limited (i.e., focal) aquatic communities?

The vital signs for each question are, respectively:

- 1) Water quality characteristics of surface and subterranean freshwater resources, and marine resources; and
- 2) Aquatic biota and communities.

Priority Water Quality Issues Associated with Monitoring Questions

Detailed assessment and refinement of priority issues specific to KLMN water quality and the two monitoring questions identified in the previous section began in October 2004. The process was initiated by sending an Aquatic Resources and Water Quality Questionnaire (see Attachment II) to the Chief of Resources Management of each park unit. Park-specific information was sought in five basic categories: (1) identification of aquatic resources within park unit boundaries (i.e., marine, estuarine, lotic, lentic, palustrine, ice caves, and geothermal/hydrothermal); (2) a list of water bodies of particular importance or interest to the park unit management; (3) a list of past and current water quality monitoring efforts; (4) a list of water resource management and/or land use issues that impact resources from either within or outside each park unit; and (5) qualification of the level of knowledge and experience of park unit staff in monitoring water quality. All park units except ORCA were able to complete and return the questionnaire. Answers to the questionnaire categories were summarized into preliminary park-specific Vital Signs Tables that included columns for: (1) Aquatic Resource; (2) Potential Resource Stressors; (3) Potential Indicators of Stress; (4) Potential Monitoring Options; and (5) Stressor Priority. (The Oregon Caves Vital Signs Table was completed at the December 1, 2004 scoping session described below.)

The preliminary Vital Signs Tables were presented to representatives of each park unit at the Klamath Network Inventory and Monitoring Program Board of Directors Meeting (FY05) in Ashland, Oregon, December 1, 2004. A Water Quality Vital Signs Scoping Session was held in the afternoon from 1:15-4:30 PM, at which time the Vital Signs Tables were reviewed and refined. Session participants (Table 13) were separated into three working groups: (1) Crater Lake and Lassen; (2) Lava Beds and Redwoods; (3)

Oregon caves and Whiskeytown. The objectives of the small groups were, for each park unit, to: (1) identify water quality stressors, indicators of stress, and stress-specific monitoring options; and (2) prioritize aquatic resource stressors. Final park-specific Vital Signs Tables were then developed based on feedback from the small groups (Tables 14-20).

Table 13. Participants at the Water Quality Vital Signs Scoping Meeting, Ashland, Oregon, December 1, 2004.

Participant	Affiliation
David Anderson	REDW
Jon Arnold	LAVO
Larry Bancroft	CRLA
Mac Brock	CRLA
Mark Buktenica	CRLA
Chris Currens	USGS WERC
Paul DePrey	WHIS
Scott Girdner	CRLA
David Hays	LABE
Robert Hoffman	USGS FRESC
Terry Hofstra	REDW
Louise Johnson	LAVO
David Larson	LABE
Mary Ann Madej	USGS WERC
Tom Marquette	REDW
Brian Rasmussen	WHIS
John Roth	ORCA
Howard Sakai	REDW
Robert Truitt	KLMN

The Vital Signs Tables created during this process include monitoring options useful in detecting potential resource change due to stress of natural or anthropogenic origin. These suggested options are not intended as a complete list of potential monitoring procedures useful for detecting ecosystem change, and the list of options can be amended as necessary during future program assessments. In addition to these options, several field measured parameters will be required as part of any monitoring program. These required parameters include: (1) water temperature; (2) specific conductance (as well as salinity in marine systems); (3) pH; and (4) dissolved oxygen. At flowing sites, some measure of qualitative flow will be required, and an estimate of water body stage or level will be required at non-flowing/still freshwater sites. Additional required parameters at marine sites include tidal stage and estimated wave height. Guidance concerning these required parameters is available in the National Park Service Water Resources Division draft document titled “Vital Signs Long-term Aquatic Monitoring Projects: Part C, Draft Guidance on WRD Required and Other Field Parameter Measurements, General Monitoring Methods and some Design Considerations in Preparation of a Detailed Study

Plan (August 2003).” This document is available on the National Park Service Inventory and Monitoring Program website at:
<http://science.nature.nps.gov/im/monitor/protocols/wqPartC.doc>.

6.0.3 Park-level Vital Signs Tables

Crater Lake National Park (CRLA)

Crater Lake aquatic resources occur within and outside of the Mt. Mazama caldera. Crater Lake is the focus of most park visitors, and a long-term monitoring program of lake and inner-caldera streams and springs water quality has been active since June, 1983. Geothermal sites deep in Crater Lake are also identified as an important resource within the caldera. Freshwater resources outside of the caldera include: (1) relatively small and shallow ponds, lakes, and wetlands; (2) Sphagnum Bog Research Natural Area; and (3) numerous streams and springs. Stressors of Crater Lake, inner-caldera streams and springs, and lentic systems outside of the caldera, in order of priority, are: (1) climate change; (2) introduced aquatic species; (3) atmospheric deposition of nutrients and pollutants; and (4) recreational use (e.g., hiking, backpacking, camping) and motorized boat use (Crater Lake only). Stressors of perennial streams and springs outside of the caldera, in order of priority, are: (1) introduced aquatic species; (2) atmospheric deposition of nutrients and pollutants; and (3) park operations (e.g., construction, and parking lot and road maintenance. Cattle trespass is identified as a potential stressor of Sphagnum Bog RNA. There is also concern that geothermal exploration near the CRLA boundary could negatively impact geothermal sites within the caldera. A detailed summary of Crater Lake aquatic resource stressors, stress indicators and associated monitoring options is provided in Table 14A-D.

Lassen Volcanic National Park (LAVO)

Aquatic resources in Lassen can be grouped into two categories: (1) ponds and lakes, wetlands, and streams; and (2) geothermal/hydrothermal features such as hot springs and streams, fumaroles, and mudpots. Ponds and lakes, wetlands, and streams are grouped together because the same stressors impact each resource-type. Stressors of lentic and lotic resources, in order of priority, are: (1) climate change; (2) atmospheric deposition of pollutants and nutrients; (3) introduced aquatic species (esp., non-native trout and charr); and (4) recreational use (e.g., hiking, backpacking and camping) and park operations (e.g., parking lot and road maintenance, and various construction projects). Visitor use is identified as the major stressor of geothermal/hydrothermal resources in Lassen. Geothermal/hydrothermal resources have been and continue to be monitored as part of the USGS Volcano Monitoring Program. A detailed summary of Lassen aquatic resource stressors, stress indicators and associated monitoring options is provided in Table 15A-B.

Lava Beds National Monument (LBE)

There are no permanent surface freshwater resources within the boundaries of Lava Beds. However, a few intermittent-ephemeral ponds do occur. Aquatic resources in Lava Beds occur primarily as ice and water in permanent ice caves and seasonal wet caves, and groundwater. Stressors of these resources include reduced precipitation associated with increased air temperatures and evaporation, and decreased relative humidity in caves. These changes could subsequently decrease the amount of ice in caves and the availability of water for Lava Beds biota. Since water is a precious commodity in Lava Beds, any change in water availability due either to stress of natural or anthropogenic origin could be quite detrimental to Lava Beds ecosystems. Stressors of anthropogenic origin include climate change, as well as geothermal exploration, agricultural land use (esp., irrigation and use of chemicals), and timber harvest just outside of the Lava Beds boundary. The priority stressors of Lava Beds aquatic resources are: (1) climate change; (2) geothermal exploration and agricultural activities near the Lava Beds boundary; (3) agricultural chemicals in cave ice and water; and (4) activities associated with park unit development, visitor use, and water runoff from park unit roads. A detailed summary of Lava Beds aquatic resource stressors, stress indicators and associated monitoring options is provided in Table 16A-D.

Oregon Caves National Monument (ORCA)

The aquatic resources of Oregon Caves consist of an in-cave stream and springs, and surface streams. Stressors to in-cave resources include: (1) climate change; (2) human actions that modify the cave environment, especially modification of cave openings; (3) visitor use impairments due to the introduction of inorganic and organic contaminants; (4) manipulation of the cave environment through the introduction of artificial light; (5) subsequent increase in algal growth in the cave and the introduction of contaminants (e.g., bleach) during cave algae control efforts; and (6) decrease in the amount and availability of in-cave water due to withdrawal of water from surface streams for fire suppression. Surface streams are susceptible to the effects of climate change, catastrophic fire, and debris flows. Cave Creek, a primary stream flowing through Oregon Caves, is also particularly susceptible to contamination by drain field leaching. The presence of grazing cattle near Oregon Caves streams may also contribute to the potential contamination of the Oregon Caves water supply. The priority stressors of Oregon Caves aquatic resources are: drain field contamination of Cave Creek; (2) human modification of the cave environment; (3) visitor introduction of contaminants into the cave; and (4) the use of artificial light in the cave. A detailed summary of Oregon Caves aquatic resource stressors, stress indicators and associated monitoring options is provided in Table 17A-B.

Redwood National and State Parks (RNSP)

Freshwater and marine aquatic resources are present in Redwoods. Freshwater resources include impaired streams (i.e., Redwood Creek and Klamath River), numerous unimpaired streams (e.g., Godwood Creek, Hayes Creek, Little Lost Man Creek, Mill

Creek, Upper Prairie Creek, and Smith River), and small ponds and wetlands. Marine resources include the inter-tidal and offshore coastal zones, the estuaries of Redwood Creek and Klamath River, several lagoons (i.e., Espa, Lagoon Creek, and Freshwater), and coastal ponds at Enderts Beach.

Redwood Creek and Klamath River are listed under section 303(d) of the Clean Water Act for high water temperature and unacceptable levels of sedimentation and nutrients (see Table 1). Additional stressors include: (1) the presence of introduced invasive species; (2) upstream land use activities (e.g., timber harvest, use of herbicides, and controlled burns); (3) highway- and levee-related perturbations (e.g., road and culvert failures, runoff and toxic spills, and levee maintenance); (4) contamination from septic system leaching and illegal garbage/trash dumping; and (5) riparian/bank disturbance associated with recreational fishing. Park watershed rehabilitation activities and in-channel gravel extraction additionally impact Redwood Creek. The unimpaired sites will be useful for determining baseline water quality characteristics and range of natural variation of Redwoods streams. Immediate stressors to these systems include runoff and toxic spills from State Highway 229 and U.S. Highway 101 and groundwater draw-down at the Mill Creek Campground.

Stressors affecting marine resources vary according to resource-type. Inter-tidal and offshore coastal areas can be affected by: (1) climate change and climatic events such as El Niño; (2) offshore oil spills and the dumping of garbage/plastics; (3) reduced downstream sediment transport due to the presence of Klamath River dams; and (4) commercial fishing of smelt and rockfish. Estuaries are affected by changes in hydrology, increased water temperatures, runoff and spills from US Highway 101, and the removal and illegal cutting of wood. The Redwood Creek estuary is also impacted by human activities that degrade riparian habitat, and by dairy farming and flood control projects. Lagoons and coastal ponds can be stressed by human-related perturbations associated with road drainage and maintenance, park development, and potential toxic contamination from an old mill site. The presence or possible introduction of various non-native invasive species (e.g., algae and invertebrates, European beachgrass, and numerous other exotic plants, etc.) can affect all marine resource-types.

The priority stressors of Redwoods freshwater resources are: (1) problems associated with 303(d) listed streams (Redwood Creek and Klamath River); (2) upstream land use; (3) recreational fishing; and (4) introduced exotic biota. The priority stressors of REDW marine resources are: (1) commercial fishing; (2) impacts related to flood control and dairy farming (Redwood Creek only); (3) invasive biota; and (4) offshore oil spills and garbage/plastics dumping. A detailed summary of Redwoods aquatic resource stressors, stress indicators and associated monitoring options is provided in Tables 18A-C and 19A-C.

Whiskeytown National Recreation Area (WHIS)

Whiskeytown aquatic resources include Whiskeytown Lake, perennial streams, mineral springs, permanent and intermittent small-shallow ponds, and marshes. Water related

activities (e.g., boating, sailing, water skiing, kayaking, swimming, fishing, etc.) are the primary recreational focus of visitors to Whiskeytown Lake and are potential stressors of reservoir water quality. Additional stressors related to human activity include: park unit sewage treatment and wastewater discharge by surrounding communities; marijuana farming and heavy metals contamination from past mining operations on the upstream sections of reservoir tributaries; and water level fluctuations caused by reservoir dam operations. As is the case with many large water bodies in the western USA, the introduction of non-native invasive floral and faunal species impact the native biota of Whiskeytown Lake. Impacted perennial streams have been affected by human-related activity (e.g., past mining operations; treatment and disposal of human waste; marijuana farming; recreation; deteriorating abandoned logging roads; gravel injection and waste rock disposal; prescribed/natural fires and related activities; floods; and introduced non-native invasive biota). There are unimpaired perennial streams in Whiskeytown and they can be used to determine baseline lotic water quality conditions and range of natural variation. However, these streams can also be affected by perturbations of natural and anthropogenic origin. There is also present in Whiskeytown an area with a complex of mineral springs that supports a small, indigenous population of Howell's alkali grass (*Puccinellia howellii*). The plant is listed by the California Native Plant Society as rare and endangered. Stressors to this resource include: (1) visitor use (e.g., litter and garbage dumping, trampling, and off-road vehicle use); (2) change in hydrology; (3) State Highway 299 maintenance and contamination/pollution due to vehicle use and accidents; and (4) potential invasion by saltgrass (*Distichlis spicata*). Little is known about the various permanent and intermittent small-shallow ponds and marshes that occur in Whiskeytown. They, like the unimpaired perennial streams, are susceptible to various types of stress of natural and anthropogenic origin. The priority stressors of Whiskeytown aquatic resources are: (1) heavy metals contamination from past mine operations and tailings; (2a) park unit sewage treatment and disposal; (2b) septic tanks, garbage/trash, and marijuana farming; and (3) natural and prescribed fire. A detailed summary of Whiskeytown aquatic resource stressors, stress indicators and associated monitoring options is provided in Table 20A-E.

Table 14. Crater Lake National Park Vital Signs Tables.

A: Crater Lake and inner-caldera streams and springs; ponds, lakes and wetlands outside of caldera

Priority	Stressors	Potential Indicators	Potential Monitoring Options
3	Atmospheric deposition of nutrients and pollutants	Change in the concentrations of air-borne nutrients (esp., nitrogen and phosphorus) and pollutants	A. Continue Crater Lake Long-term Monitoring Program B. Inventory and determine the physical, chemical and biological characteristics of lentic systems outside of the caldera C. Wet/dry chemistry: (a) rain and snow precipitation; (b) snow core D. Measure pollutants of interest in tissue samples (highest trophic-level possible) E. Rapid bioassessment of impact using aquatic macroinvertebrates as indicators
2	Introduced aquatic species	Change in the distributions, abundances, percent area occupied (PAO), and community organization and structure of native and introduced aquatic species	A. Document the distributions, abundances, (PAO), and community organization and structure of native and introduced aquatic species
4	Recreational use (e.g., hiking, back-packing, camping) of non-caldera sites; and motorized boat use on Crater Lake	Change in rates of sedimentation, aquatic macroinvertebrate occurrence (species and community composition), shoreline/riparian impact, and presence of hydrocarbons	A. Document, map, and photo-archive shoreline condition of non-caldera sites B. Collect sediment cores to document historical and contemporary sedimentation rates C. Determine macroinvertebrate species distribution and community composition in all aquatic habitats at each site and use rapid bioassessment methods to identify and quantify impact D. Measure chlorophyll-a concentration in phytoplankton and periphyton E. Analyze Crater Lake water for hydrocarbons
1	Climate change	Change in parameters such as water temperature, precipitation, water-level, ozone, UVB radiation, etc.	A. Measure water temperature, precipitation, water-level, ozone, UVB radiation, etc.

Table 14: Crater Lake National Park Vital Signs Tables continued

B: Sphagnum Bog Research Natural Area

Priority	Stressors	Potential Indicators	Potential Monitoring Options
	All stressors in 1A plus cattle trespass	Change in the physical, chemical and biological characteristics of the bog	A. Determine physical, chemical and biological characteristics, range of natural variation, and monitor for disturbance

C: Perennial streams and springs outside of the caldera.

Priority	Stressors	Potential Indicators	Potential Monitoring Options
1	Introduced aquatic species	Change in the distributions, abundances, percent area occupied (PAO), and community organization and structure of native and introduced aquatic species	A. Document the distributions, abundances, PAO, community organization and structure of native and introduced aquatic species
2	Atmospheric deposition of nutrients and pollutants	Change in the concentrations of air-borne nutrients (esp., nitrogen and phosphorus) and pollutants	A. Inventory and determine the physical, chemical and biological characteristics of lotic systems B. Wet/dry chemistry: (a) rain and snow precipitation; (b) snow core C. Measure periphyton chlorophyll-a concentration D. Measure pollutants of interest in tissue samples (highest trophic-level possible) E. Rapid bioassessment of impact using aquatic macroinvertebrates as indicators
3	Park operations (e.g., construction, parking lot and road maintenance)	Change in rates of sedimentation, aquatic macroinvertebrate occurrence (species and community composition), shoreline/riparian impact, increase in hydrocarbons and other pollutants	A. Collect sediment cores to determine historical and contemporary sedimentation rates B. Determine species distribution and composition in all aquatic habitats C. Rapid bioassessment of impact using aquatic macroinvertebrates as indicators D. Analysis of stream water and runoff from parking lots and roads for hydrocarbons and other potential pollutants E. Measure periphyton chlorophyll-a concentration

D: Subsurface geothermal sites in Crater Lake

Priority	Stressors	Potential Indicators	Potential Monitoring Options
	Geothermal exploration near Park	Change in chemistry, discharge, temperature, etc.	A. Inventory and determine baseline conditions and natural variation of chemistry, flow and discharge, temperature, bacteria and other associated biota

Table 15. Lassen Volcanic National Park Vital Signs Tables.

A: Ponds, lakes, wetlands and perennial streams

Priority	Stressors	Potential Indicators	Potential Monitoring Options
2	Atmospheric deposition of air-borne nutrients (esp., nitrogen and phosphorus) and pollutants	Change in the concentrations of nutrients and pollutants	<p>A. Wet/dry chemistry: (a) rain and snow precipitation; (b) snow core</p> <p>B. Chemical analysis of water samples with emphasis on nutrients</p> <p>C. Tissue sample analysis (highest trophic-level possible) to determine concentrations of pollutants</p> <p>D. Measure chlorophyll-a concentration in phytoplankton and periphyton</p> <p>E. Rapid bioassessment of impact using aquatic macroinvertebrates as indicators</p>
3	Introduced aquatic species	Change in the distributions, abundances, percent area occupied (PAO), and community organization and structure of native and introduced aquatic species	A. Document the distributions, abundances, PAO, and community organization and structure of native and introduced aquatic species
4	Recreational use (e.g., hiking, backpacking, camping) and Park operations (e.g., construction, parking lot and road maintenance)	Change in sedimentation rates, aquatic macroinvertebrate occurrence (species and community composition), shoreline/riparian impact, and increase of pollutants	<p>A. Collect sediment cores to determine historical and contemporary sedimentation rates</p> <p>B. Determine macroinvertebrate species distribution and community composition in all aquatic habitats</p> <p>C. Rapid bioassessment of impact using aquatic macroinvertebrates as indicators</p> <p>D. Analysis of stream water and runoff from parking lots and roads for hydrocarbons and other pollutants</p> <p>E. Measure chlorophyll-a concentration in phytoplankton and periphyton</p>
1	Climate change	Change in parameters such as water temperature, precipitation, water-level, ozone, UVB radiation, etc.	A. Measure precipitation, water temperature, water-level, flow rates, UVB radiation, ozone, etc.

B: Geothermal/hydrothermal

Priority	Stressors	Potential Indicators	Potential Monitoring Options
	Visitor use	Change in measured parameters (e.g., water chemistry and temperature, flow, discharge, etc.)	A. Continue on-going monitoring as part of USGS Volcano Monitoring Program

Table 16. Lava Beds National Monument Vital Signs Tables.**A: Permanent ice caves**

Priority	Stressors	Potential Indicators	Potential Monitoring Options
1	Climate change (esp., increased air temperatures and reduced precipitation)	Change in air temperature and relative humidity in caves	A. Identify and inventory ice sources B. Measure air temperature, relative humidity, and ice-levels in caves C. Chemical analysis of ice samples for basic water quality and concentrations of hydrocarbons and agricultural chemicals of interest
	Change in air currents and movement	Change in ice chemistry and ice levels in caves	
3	Concentrations of agricultural chemicals in cave ice and water	Increase in the concentrations of agricultural chemicals and hydrocarbons in ice and water in caves	
4	Activities associated with Park development, visitor use, and water runoff from Park roads		

B: Seasonal ice caves

Priority	Stressors	Potential Indicators	Potential Monitoring Options
	Nearby geothermal exploration and agricultural activities	Change in the physical, chemical and biological characteristics of caves	A. Measure air temperature, relative humidity, and available water in caves B. Identify biota residing in or using caves and document resident community organization and structure and rates of use by non-resident biota C. Document physical characteristics of caves and quality of available water (including concentrations of agricultural chemicals of interest)

C: Intermittent ephemeral ponds

Priority	Stressors	Potential Indicators	Potential Monitoring Options
	Climate change (esp., increased air temperatures and reduced precipitation)	Change in the timing, longevity and physical characteristics of ponds	A. Identify and inventory ponds B. Document timing, longevity and physical characteristics of ponds C. Determine water quality (esp., chemistry and biology)

D: Groundwater

Priority	Stressors	Potential Indicators	Potential Monitoring Options
2	Nearby geothermal exploration, agricultural activities (esp., irrigation and chemical use) and timber harvest	Change in the availability, depth and quality of groundwater	A. Determine the physical and chemical characteristics of groundwater throughout the Park

Table 17. Oregon Caves National Monument Vital Signs Tables.

A: In-cave stream and springs

Priority	Stressors	Potential Indicators	Potential Monitoring Options
2	Modified cave openings Climate change	Changes in cave environment including air temperature, evaporation rates, relative humidity and concentrations of total carbonates, chloride and total dissolved solids	A. Measure air temperature, evaporation, relative humidity and concentrations of total carbonates, chloride and total dissolved solids B. Identify, inventory and determine abundance of cave-adapted biota C. Document timing and extent of snowmelt D. Monitor calcite solubility
3	Visitor use	Change in the presence and amount of litter and organic contaminants (e.g., lint)	A. Identify and inventory presence of litter and organic contaminants and monitor for change
4	Manipulation of cave environment (esp., light)	Effect of the timing and duration of artificial light on cave-adapted biota and potential increase in abundance of light-adapted biota	A. Measure timing and duration of artificial light B. Identify and inventory the presence and abundance of cave- and light-adapted biota
	Control of algae	Increase in the presence and concentrations of sodium hypochlorite and hydrogen peroxide in water samples	A. Measure presence and concentrations of sodium hypochlorite and hydrogen peroxide in water samples
	Use of surface water for fire suppression	Change in flow rates and availability (i.e., quantity) of water in cave stream and springs	A. Measure flow and discharge of cave stream and springs

B: Perennial surface streams

Priority	Stressors	Potential Indicators	Potential Monitoring Options
1	Drain field contamination of Cave Creek	Increase in nitrate, orthophosphate and fecal coliform concentrations, and changes in the presence of aquatic macroinvertebrate species and community composition	A. Measure nitrate, orthophosphate and fecal coliform concentrations in water samples B. Identify and inventory macroinvertebrate species distribution and community composition in Cave Creek; use rapid bioassessment methods to identify change
	Debris flows and catastrophic fire	Increase in bank and channel erosion, sediment input and loss of water clarity	A. Measure channel longitudinal profile, frequency and distribution of upwelling zones, flow and discharge rates, bedload, and concentrations of suspended and total dissolved solids
	Port Orford cedar root rot	Presence of the fungus <i>Phytophthora lateralis</i> and dead trees	A. Identify, inventory and monitor vegetation patterns and number and distribution of dead trees
	Climate change	Change in the timing, depth and duration of snow pack and quantity of surface water	A. Measure the timing, depth and duration of snow pack B. Measure flow and discharge rates of streams
	Cattle grazing near water supply	Presence of <i>Giardia</i> and <i>Cryptosporidium</i> in water supply	A. Monitor for presence of <i>Giardia</i> and <i>Cryptosporidium</i> in samples from water supply

Table 18. Redwood National and State Parks Vital Signs Tables (freshwater).

A: Impaired perennial streams (Redwood Creek and Klamath River)

Priority	Stressors	Potential Indicators	Potential Monitoring Options
1	303(d) listed for high water temperatures, nutrients and sedimentation/siltation	Change in the physical, chemical, and biological characteristics of streams including: (1) water temperature, (2) sedimentation rate and clarity, (3) flow and discharge rates, (4) nitrogen concentration, (5) primary productivity, (6) presence and abundance of native and invasive biota, (7) presence and concentrations of herbicides, (8) presence of highway and motor vehicle derived contaminants, (9) presence of bacterial indicators of fecal contamination	A. Rapid bioassessment of impact using aquatic macroinvertebrates as indicators
	Invasive species (i.e., catfish)		B. Water temperature monitoring
2	Upstream land use/timber harvest, herbicide application, lack of woody debris, and controlled burns		C. Measure suspended sediment and turbidity, bedload, flow and discharge
	Roads and road failures, Hwy 101 bypass runoff and spills		D. Mainstem cross-sections
	Private septic systems and illegal dumping of garbage and trash		E. Status and trends of native and invasive biota (esp., anadromous fish, catfish, amphibians)
	Park watershed rehabilitation and gravel removal (Redwood Creek only)		F. Measure nitrogen concentration and bacterial indicators of fecal contamination near suspected septic drain field effluent encroachment
3	Recreational fishing		G. Exploratory wells
	Levee maintenance		H. Status and trends of water chemistry and assessment of presence of highway and motor vehicle derived contaminants

B: Unimpaired perennial streams (e.g., Godwood, Upper Prairie, and Hayes Creeks; Smith River)

Priority	Stressors	Potential Indicators	Potential Monitoring Options
	Useful as reference sites for baseline water quality data and determination of range of variability	Change in the physical, chemical, and biological characteristics of streams including: (1) water temperature, (2) sedimentation rate and clarity, (3) flow and discharge rates, (4) nitrogen concentration, (5) primary productivity, (6) presence and abundance of native biota, (7) occurrence of invasive biota (8) salmonid spawning activity and recruitment, (9) abundance of large woody debris	A. Assessment of water temperature, suspended sediment and turbidity, bedload, flow and discharge
	Groundwater draw-down at Mill Creek Campground		B. Rapid bioassessment of impact using aquatic macroinvertebrates, fish and freshwater mussels as indicators
	Hwy 199 and 299 runoff and spills		C. Large woody debris surveys
			D. Status and trends of anadromous and resident fish, and native amphibians
			E. Fish carcass and redd surveys
			F. Water table monitoring
			G. Status and trends of water quality

Table 18: Redwood National and State Parks Vital Signs Tables (freshwater continued)

C: Freshwater ponds and wetlands (Marshall Pond, small ponds at Gold Bluffs Beach)

Priority	Stressors	Potential Indicators	Potential Monitoring Options
4	<p>Atmospheric deposition of nutrients and other pollutants, and air quality</p> <p>Introduced exotic plants, bullfrogs and fish</p> <p>Former mill site</p>	<p>Change in the physical, chemical and biological characteristics of ponds and wetlands beyond natural variation</p>	<p>A. Status and trends of present water quality conditions and range of variation</p> <p>B. Inventory community composition of aquatic biota and determine extent of presence of introduced biota</p> <p>C. Status and trends of native amphibians</p> <p>D. Rapid bioassessment of impact using aquatic macroinvertebrates as indicators</p>

Table 19. Redwood National and State Parks Vital Signs Tables (marine).

A: Inter-tidal and offshore coastal

Priority	Stressors	Potential Indicators	Potential Monitoring Options
4	Climate change and events (e.g., El Niño)	Change in ocean processes (e.g., upwelling, wave action, nearshore currents), water and air temperature, ozone, UVB radiation	A. Status and trends of wave action, nearshore currents and upwelling, and monitor for change beyond natural range of variation
	Offshore oil spills and dumping of garbage/plastics	Catastrophic mortality of shorebirds and marine biota	B. Measure water and air temperatures, ozone, UVB radiation
3	Invasive biota (e.g., European beachgrass, invertebrates, algae, etc.)	Increase in presence of invasive species concordant with decline in native species	C. Status and trends of seabirds/shorebirds and coastal invertebrates and use indicator species for rapid bioassessment of impacts
1	Sediment flux from Klamath River dams	Change in smelt and rockfish abundances	D. Assess distribution of sediment composition and particle size, and status and trends of sediment flux
	Commercial fishing (e.g., smelt, nearshore rockfish fishery)		E. Status and trends of smelt and rockfish populations F. Status and trends of ocean and tidal water chemistry G. Status and trends of native and introduced/invasive biota

B: Lagoons (Espa, Lagoon Creek, Enderts Beach pond)

Priority	Stressors	Potential Indicators	Potential Monitoring Options
	Sedimentation due to roads, culverts, road drainage and Park development	Increase in sedimentation rate and decrease in water-level and depth	A. Measure water-level and depth
	Water contamination from old mill site	Presence of toxins in water and tissue samples	B. Assess plant community composition and monitor for change
	Introduced/invasive species (e.g., fish stocking and aquatic weeds)	Presence of introduced/invasive species with concordant decrease in native biota	C. Status and trends of water quality and presence of toxins D. Status and trends of native and introduced/invasive biota; also status and trends of amphibians (primarily anurans)

Table 19: Redwood National and State Parks Vital signs Tables (marine continued)

C: Estuaries (Redwood Creek, Klamath River)

Priority	Stressors	Potential Indicators	Potential Monitoring Options
2	<p>Invasive species/exotic grasses (e.g., canary grass)</p> <p>Hydrological changes and increased water temperatures</p> <p>Human impact (Redwood Creek only); degraded riparian habitat; flood control projects (levees); dairy farming</p> <p>Illegal woodcutting</p> <p>Hwy 101 bypass runoff and spills</p>	<p>Increase in the presence of invasive species/exotic grasses and decrease in native species (including threatened and endangered species)</p> <p>Continued degradation of riparian habitat</p> <p>Change in sediment deposition, water temperature and flow, and distribution of large woody debris</p> <p>Presence of bacterial indicators of fecal contamination (Redwood Creek only)</p> <p>Presence of highway and motor vehicle derived contaminants</p>	<p>A. Sediment surveys and status and trends of sediment deposition</p> <p>B. Canary grass surveys</p> <p>C. Status and trends of riparian habitat</p> <p>D. Large woody debris surveys</p> <p>E. Water temperature and flow monitoring</p> <p>F. General water quality monitoring (esp., bacterial indicators of fecal contamination, Redwood Creek only)</p> <p>G. Status and trends of native and introduced/invasive species</p> <p>H. Determination of the presence and status and trends of highway and motor vehicle derived contaminants</p>

Table 20. Whiskeytown National Recreation Area Vital Signs Tables.

A: Whiskeytown Lake (Reservoir)

Priority	Stressors	Potential Indicators	Potential Monitoring Options
	<p>Visitor use: terrestrial, boating, swimming and other water-related activities</p> <p>Upstream marijuana farming</p>	<p>Beach and shoreline erosion</p> <p>Increase in: bacterial indicators of fecal contamination, nitrogen and phosphorus due to fertilizer use, herbicides and pesticides, and petroleum-based contaminants</p>	<p>A. Status and trends of water quality (esp., nutrients and hydrocarbons)</p> <p>B. Measure concentrations of fecal indicator bacteria</p> <p>C. Measure concentrations of herbicides and pesticides in tissue samples (highest trophic-level possible)</p> <p>D. Document presence of petroleum-based discharges on water surface</p> <p>E. Inventory and measure indicators of beach/shoreline erosion (vegetation and trail impact mapping, photo-archive, sediment cores)</p>
2a	Park sewage treatment and waste water discharge of surrounding communities	Increase in concentrations of nitrate and phosphorus and presence of bacterial indicators of fecal contamination	A. Measure nitrate and phosphorus concentrations near potential discharge sites and test for fecal indicator bacteria
	Invasive biota	Increase in occurrence and abundance of invasive species	A. Status and trends of invasive species: presence, abundance, rates of recruitment and mortality
	Water level fluctuations due to reservoir operations and evaporation	Increase in nearshore sedimentation, change in beach profiles and aquatic macroinvertebrate species presence and community organization	<p>A. Measure total dissolved solids and rates of sedimentation</p> <p>B. Photo-archive and map beach profiles</p> <p>C. Monitor reservoir water-level</p> <p>D. Inventory macroinvertebrates species distribution and community organization in all nearshore habitats; assess using rapid bioassessment methods</p>
	Presence of the dam	Disruption of native salmonid passage into upper reaches of reservoir tributaries	A. Measure presence and abundance of salmonids below and above dam
	Heavy metals	Presence and increase in concentrations of heavy metals in reservoir water	A. Measure concentrations of heavy metals (e.g., mercury, cadmium, nickel, iron, and arsenic) in tissue samples (highest trophic-level possible)

Table 20: Whiskeytown National Recreation Area Vital Signs Tables (continued)

B: Impaired perennial streams

Priority	Stressors	Potential Indicators	Potential Monitoring Options
1 2b	Human impacts including: - mine operations and tailings - septic tanks, garbage, trash and marijuana farming - visitor use (e.g., horses and mountain bikes)	Increase in concentrations of heavy metals, nitrogen, phosphorus, herbicides and pesticides; presence of fecal indicator bacteria; change in sedimentation rate, water clarity and temperature; soil compaction leading to lower infiltration rates; increase in the presence of litter and trash	A. Status and trends of water quality (esp., nitrogen, phosphorus, pH, conductivity, total dissolved solids) B. Measure concentrations of fecal indicator bacteria C. Monitor for the presence of oil products and other hazardous wastes, litter and trash D. Measure sedimentation rate, turbidity, bedload, water temperature E. Photo-archive and map shoreline soil compaction F. Inventory macroinvertebrate species distribution and community organization in all aquatic habitats; assess using rapid bioassessment methods G. Measure heavy metals concentrations in tissue samples
	Gravel injection; sedimentation due to roads and deteriorating condition of abandoned logging roads; waste rock disposal	Change in sedimentation rates, channel morphology, flow regime, biota, and metals content	A. Measure suspended and total dissolved solids, turbidity, bedload, water temperature and pH B. Measure channel morphology (e.g., pool/riffle sequence, channel width/depth profiles) C. Measure heavy metals concentrations in tissue samples (highest trophic-level possible)
	Species of concern and invasive species	Decline in species of concern	A. Status and trends of species of concern and invasive species: presence, abundance, rates of recruitment and mortality B. Inventory and determine condition of habitat quality of species of concern
3	Fire: prescribed burns, natural wildfires, construction of fuel breaks, other fire-related activities	Change in physical, chemical, and biological characteristics of streams	A. Measure sedimentation rate, turbidity, bedload, water temperature B. Measure channel morphology (e.g., pool/riffle sequence, channel width/depth profiles) C. Measure water chemistry (esp., nitrogen) D. Rapid bioassessment of impact using aquatic macroinvertebrates as indicators
	Floods (natural and due to water release from dam)	Change in water temperature and concentrations of heavy metals	A. Measure water temperature and heavy metal concentrations

C: Unimpaired perennial streams

Priority	Stressors	Potential Indicators	Potential Monitoring Options
	Impacts of natural and anthropogenic origin	Change in physical, chemical and biological characteristics of streams beyond range of natural variation	A. Status and trends of stream characteristics B. Status and trends of species of concern and invasive species : presence, abundance, rates of recruitment and mortality

Table 20: Whiskeytown National Recreation Area Vital Signs tables (continued)

D: Mineral springs complex and Howell's alkali grass (*Puccinellia howellii*)

Priority	Stressors	Potential Indicators	Potential Monitoring Options
	<p>Hwy 299: accidents, construction, maintenance, hydrocarbon pollution, and other contaminants</p> <p>Visitor use: litter and garbage dumping, vehicle parking and off-road use, trampling</p> <p>Change in hydrology</p> <p>Invasion and exclusion by salt-grass (<i>Distichlis spicata</i>)</p>	<p>Decline in already small population size of indigenous Howell's alkali grass</p>	<p>A. Status and trend of Howell's alkali grass population and saltgrass (esp., inventory, map, and photo-archive)</p> <p>B. Monitor hydrology of springs</p> <p>C. Determine visitor use and types of pollution; monitor for impact</p>

E: Permanent small-shallow ponds, intermittent ephemeral ponds, marshes

Priority	Stressors	Potential Indicators	Potential Monitoring Options
	<p>Impacts of natural and anthropogenic origin</p>	<p>Change in the physical, chemical and biological characteristics of these resources beyond the range of natural variation</p>	<p>A. Inventory sites and determine status and trends of resource characteristics</p>

2.0.4 Network-level Vital Signs Assessment

Resource Stressors

Five general stressor categories (Table 21) were identified as potentially affecting Klamath Network park unit freshwater resources: (1) atmospheric deposition of nutrients (e.g., nitrogen and phosphorus) and pollutants (e.g., mercury, persistent organics flame retardants, water-repellent coatings, etc.); (2) introduced/invasive non-native biota (e.g., bullfrogs, exotic fish, invertebrates, algae, etc.); (3) climate change (e.g., changes in air and water temperature regimes and the timing and longevity of precipitation events and snow pack, etc.); (4) visitor recreational activities; and (5) land use and non-recreational human impacts. Visitor recreational activities were divided into four subcategories ranging from general impacts in the more developed and maintained areas in park units to backcountry impacts caused by activities such as hiking, backpacking and camping. Land use stressors were divided into 15 subcategories representing activities that include road construction and maintenance, treatment and deposition of human waste, dam operation and maintenance, agriculture, and past and present resource extraction operations (e.g., mining, timber harvest, geothermal exploration). Lentic, lotic, and unique water resources were identified as susceptible to a relatively high number of potential stressors (i.e., 12 of 22 [55%], 15 of 22 [68%] and 10 of 22 [45%], respectively; Table 22). Lotic systems were also identified as especially susceptible to stressors associated with land use activity (i.e., 10 of 15 stressors compared to 6 of 15 stressors for lotic and unique water resources; Table 22). The primary stressors of cave water resources (e.g., ice, streams and springs) were identified as climate change, impacts due to visitation, manipulation of the cave environment, park unit operations and nearby agricultural activities, and activities associated with fire suppression. Geothermal/hydrothermal resources were identified as being generally affected by visitor use and geothermal exploration near, yet outside park unit boundaries.

The three Redwoods marine resource-types were identified as being variously affected by three of the five general stressor categories: (1) climate change; (2) introduced/invasive non-native biota; and (3) land use and non-recreational human impacts (Table 23). The land use-human impacts category was divided into nine subcategories of stressors. Climate change was identified as affecting only the inter-tidal/coastal offshore resource-type, whereas introduced/invasive non-native biota was an important stressor in lagoons and estuaries. Each resource-type was identified as being susceptible to two or more kinds of human/land use impacts.

Table 21. Stressors affecting freshwater resources in each Klamath Network Park Unit.

Stressors	CRLA	LAVO	LABE	ORCA	REDW	WHIS
1. Atmospheric deposition	X	X			X	X
2. Introduced/invasive non-native biota	X	X			X	X
3. Climate change	X	X	X	X		X
4. Visitor use – recreational						
a. General impacts		X	X	X		
b. Hiking, backpacking, camping, horses, mountain bicycles	X	X				X
c. Motorized boats and boat-related activities	X					X
d. Swimming, fishing, etc.					X	X
5. Land use and non-recreational human impacts						
a. Park operations (construction, development, parking lot/road and levee maintenance)	X	X	X	X	X	X
b. Roads: construction, maintenance, failure, culverts, runoff and spills	X	X	X		X	X
c. Past mining operations/heavy metals						X
d. Dam operations, water-level and sediment flux						X
e. Sewage treatment, wastewater discharge, septic and drain field contamination				X	X	X
f. 303(d) listed water bodies					X	
g. Former mill site and operations					X	
h. Fire: wild and prescribed; suppression				X	X	X
i. Timber harvest and operations (including herbicide application)			X		X	
j. Agriculture: contamination by fertilizers, herbicides and pesticides; irrigation			X			X
k. Manipulation of cave environment (esp., light and control of algae)				X		
l. Geothermal exploration and activities near Park boundary	X		X			
m. Litter and garbage dumping					X	X
n. Vehicle parking and off-road use						X
o. Impacts associated with cattle (grazing and trespass)	X			X		

Table 22. Stressors affecting each freshwater resource-type in Klamath Network Park Units [p = permanent; Geo/Hydro = Geothermal/Hydrothermal; unqRes = unique resource including intermittent ephemeral ponds and seasonal ice caves (LABE), mineral springs complex (WHIS), and Sphagnum Bog Research Natural Area (CRLA)].

Stressors	pLentic	pLotic	Geo/Hydro	Caves	unqRes
1. Atmospheric deposition	X	X			X
2. Introduced/invasive non-native biota	X	X			X
3. Climate change	X	X		X	X
4. Visitor use – recreational					
e. General impacts			X	X	
f. Hiking, backpacking, camping, horses, mountain bicycles	X	X			X
g. Motorized boats and boat-related activities	X				
h. Swimming, fishing, etc.	X	X			
5. Land use and non-recreational human impacts					
a. Park operations (construction, development, parking lot/road and levee maintenance)	X	X		X	
b. Roads: construction, maintenance, failure, culverts, runoff and spills		X			
c. Past mining operations/heavy metals	X	X			
d. Dam operations, water-level and sediment flux	X	X			
e. Sewage treatment, wastewater discharge, septic and drain field contamination	X	X			
f. 303(d) listed water bodies	X				
g. Former mill site and operations	X				
h. Fire: wild and prescribed; suppression		X		X	
i. Timber harvest and operations		X			X
j. Agriculture: fertilizers, herbicide and pesticide contamination, irrigation		X		X	X
k. Manipulation of cave environment (esp., light and control of algae)				X	
l. Geothermal exploration and activities near Park boundary			X		X
m. Litter and garbage dumping		X			X
n. Vehicle parking and off-road use					X
o. Impacts associated with cattle (grazing and trespass)		X			X

Table 23. Stressors identified as affecting three general types of marine resources at Redwood National and State Parks.

Stressors	Inter-tidal/ Coastal Offshore	Lagoons	Estuaries
1. Climate change	X		
2. Introduced/invasive non-native biota		X	X
3. Human/Land use impacts			
a. Oil spills	X		
b. Litter and garbage dumping	X		
c. Sediment flux (dams)	X		
d. Commercial fishing	X		
e. Sedimentation (roads, runoff, spills and culverts)		X	X
f. Contamination from old mill site		X	
g. Flood control levees			X
h. Dairy farming			X
i. Illegal woodcutting			X

Stressor Prioritization

Stressors were prioritized by staff at each park unit relative to the perceived potential of stressors to negatively impact park unit aquatic resources. The prioritization of stressors varied among the units (Table 24):

1. Crater Lake identified each of the five general stressors as a potential priority issue for the park's lentic and lotic resources;
2. Lassen did not identify any of the land use activity subcategories as potentially affecting the park's water resources;
3. Climate change was identified as the top priority stressor at Lava Beds, followed by four types of land use activities (i.e., park unit operations, timber harvest/operations, agriculture, and geothermal exploration);
4. Land use activities associated with human waste disposal and timber harvest, as well as climate change and general impacts due to visitor use were identified as priority stressors at Oregon caves;
5. Redwoods did not identify atmospheric deposition of nutrients and pollutants as a priority problem for the park's freshwater and marine resources;
6. All priority stressors at Whiskeytown were subcategories of land use activities (i.e., past mining operations, dam operation and water-level flux, and impacts due to fire and fire suppression).

Table 24. Priority ratings for each of five general aquatic resource stressor categories and their subcategories. Ratings for each Park are from 1-4 with 1 being the highest priority. The two CRLA ratings are lentic/lotic; the two REDW ratings are freshwater/marine; the two WHIS ratings are dam operations/water-level flux.

Stressors	CRLA	LAVO	LABE	ORCA	REDW	WHIS
1. Atmospheric deposition	3 / 2	2				
2. Introduced/invasive non-native biota	2 / 1	3			4 / 2	
3. Climate change	1 / -	1	1	2	- / 3	
4. Visitor use – recreational	4 / -					
a. General impacts				3		
b. Hiking, backpacking, camping, horses, mountain bicycles		4				
c. Motorized boats and boat-related activities						
d. Swimming, fishing, etc.					3 / -	
5. Land use and non-recreational human impacts					- / 1	
a. Park operations (construction, development, parking lot/road and levee maintenance)	- / 3		4			
b. Roads: construction, maintenance, failure, culverts, runoff and spills						
c. Past mining operations/heavy metals						1
d. Dam operations, water-level and sediment flux					- / 4	2a / 2b
e. Sewage treatment, wastewater discharge, septic and drain field contamination				1		
f. 303(d) listed water bodies					1 / -	
g. Former mill site and operations						
h. Fire: wild and prescribed; suppression					2a / -	3
i. Timber harvest and operations (including herbicide application)			2a	2	2b / -	
j. Agriculture: fertilizers, herbicide and pesticide contamination, irrigation			3			
k. Manipulation of cave environment (esp., light and control of algae)						
l. Geothermal exploration and activities near Park boundary			2b			
m. Litter and garbage dumping						
n. Vehicle parking and off-road use						
o. Impacts associated with cattle (grazing and trespass)						

A stressor index was calculated to determine the perceived importance of each general stressor category at the network-level. The index was calculated for each stressor by adding the priority rating (i.e., 1–4, with 1 being the highest priority) assigned to the stressor by each park unit (Table 24). If a park unit did not assign a rating to a stressor then a rating of 5 was assigned to that stressor for that unit. If a park unit assigned two or more ratings to a stressor (e.g., CRLA atmospheric deposition = 3/2; LABE land use activities = 4/2a/3/2b; Table 24) then the ratings for that stressor were averaged. The average index for all park units for each general stressor was calculated as:

1. $[CRLA + LAVO + LABE + ORCA + REDW + WHIS]/6$ park units.

For example:

1. atmospheric deposition = $[(3+2/2)+2+5+5+5+5]/6 = \mathbf{4.1}$,
2. land use = $[3+5+(4+2+3+2/4)+(1+2/2)+(1+4+1+2+2/5)+(1+2+2+3/4)]/6 = \mathbf{2.7}$.

Two basic groups of stressors were identified based on the calculation of the average index for each of the five general stressors: (1) climate change and land use activities scored 2.7; and (2) introduced/invasive biota, visitor use-recreational, and atmospheric deposition scored between 3.8 and 4.1.

- | | |
|-------------------------------|----------------------------------------------|
| 1. Climate change: | mean = 2.7, median = 1.5, 5 of 6 park units; |
| 2. Land use activities: | mean = 2.7, median = 2.4, 5 of 6 park units; |
| 3. Introduced/invasive biota: | mean = 3.8, median = 4.0, 3 of 6 park units; |
| 4. Visitor use-recreational: | mean = 4.0, median = 4.0, 4 of 6 park units; |
| 5. Atmospheric deposition: | mean = 4.1, median = 5.0, 2 of 6 park units. |

Monitoring Questions, Potential Indicators of Resource Stress and Associated Monitoring Options

A monitoring question was developed for each of the five general aquatic resource stressor categories. Each question was general in scope so as to be applicable to each park unit. Next, a list of potential stress indicators (i.e., characteristics that can be measured and are useful indicators of change and/or perturbation) for each stressor category was created by compiling and synthesizing indicators from each park-specific Vital Signs Table. Indicators were chosen that could be used to answer each monitoring question. Finally, a list of potential monitoring options consisting of a parameter or set of parameters to be sampled and useful for quantifying resource change and/or perturbation was also created by compiling and synthesizing responses from the park-specific Vital Signs Tables. This process created a relatively detailed outline of potential stress indicators and monitoring options (see pages 75-79). Indicators and monitoring options can be revised and refined as necessary during the development of the Klamath Network water quality monitoring program.

1. **Basic information** required for each resource-type:

- A. Complete inventory (or as complete as possible) of sites in each park unit.
- B. Status and trends:
 - 1) Data to elucidate the present physical, chemical and biological characteristics of (at least) a subset of sites; and
 - 2) Determination of the present variability among sites.
- C. Identification of sites potentially not affected by impacts due to visitor recreational use, park unit operations, or nearby past and present land use activities. These sites will be potentially useful for determining, at least in a relative sense, the characteristics and variation among 'pristine' sites to which impacted sites can be compared.

2. **Climate change:**

- A. Monitoring question: What impacts do global and local changes in climate have on Klamath Network park unit aquatic resources (especially regarding such parameters as the timing and extent of precipitation, water and air temperature ranges, air currents, relative humidity, evaporation rates, ozone-levels, and UVB radiation flux and attenuation); and how do these impacts affect resource condition, quality, and ecosystem dynamics?
- B. Indicators:
 - 1) Change in climate-related parameters such as (a) water and air temperature, (b) relative humidity, (c) timing and amount of precipitation (rain and snow), (d) water-level, (e) flow and discharge rates, (f) ozone levels, (g) UVB radiation flux and attenuation, and ocean processes (e.g., upwelling, wave action, nearshore currents);
 - 2) Change in the timing, longevity and physical characteristics of intermittent ephemeral ponds (primarily at LABE).
- C. Monitoring Options:
 - 1) Measure water and air temperature, relative humidity, precipitation, water-level, flow and discharge rates, ozone levels, and UVB radiation flux and attenuation;
 - 2) Determine the status and trends of wave action, upwelling, and nearshore currents; and measure for change beyond normal statistical variation;
 - 3) Document the timing, depth, and duration of snow pack; and the timing and extent of snow melt;
 - 4) Identify and inventory ice sources and intermittent ephemeral ponds (LABE);
 - 5) Determine extent of ice sources and measure ice-levels, evaporation rates, concentrations of total carbonates and calcite solubility (LABE and ORCA);

- 6) Document the timing, longevity and physical characteristics of intermittent ephemeral ponds (LBE).
3. **Land use and non-recreational human impacts** (subcategories to which indicators apply are in brackets; see Tables 14, 15, 16, or 17 for list of subcategories):
 - A. Monitoring question: How do land use activities (past, present and within and outside of Klamath Network park units) affect park unit aquatic resources; and how do these activities impact resource condition, quality, and ecosystem dynamics?
 - B. Indicators:
 - 1) Increase in sedimentation/siltation and turbidity [A, B, D, F, H, I];
 - 2) Changes in the distributions and composition of aquatic biota [A, D, E, H, I, L];
 - 3) Disturbance (e.g., trampling, rutting, erosion) of stream banks and channels, pond and lake shorelines and wetted areas [A, N, O];
 - 4) Presence of and/or increase in the concentrations of hydrocarbons and other motor vehicle derived contaminants [A, B, N];
 - 5) Increase in water temperature and decrease in dissolved oxygen level [B, F, I, L];
 - 6) Change in channel morphology (e.g., bank and channel erosion), as well as flow and discharge rates [B, H, I, L];
 - 7) Presence of and/or increase in the concentrations of heavy metals and other contaminants (e.g., herbicides, pesticides, dioxin) [B, C, G, I, J];
 - 8) Disruption of native anadromous salmonid passage [D];
 - 9) Increase in nutrients (e.g., nitrogen and phosphorus) and primary productivity [B, E, F, I];
 - 10) Presence of and/or increase in bacterial indicators of fecal contamination, *Giardia*, and *Cryptosporidium* [E, O];
 - 11) Change in the depth and quantity of groundwater [J];
 - 12) Presence of and/or increase in the abundance of light-adapted biota as well as contaminants such as hydrogen peroxide and sodium hypochlorite in caves [K];
 - 13) Presence of and/or increase in the amount of litter and garbage at or near resource sites [M].
 - C. Monitoring Options:
 - 1) Collect sediment cores to determine historical and contemporary sedimentation rates; measure turbidity, bedload, flow and discharge rates, water-level [A, B, D, F, H, I];
 - 2) Measure water temperature, dissolved oxygen level, and nutrient and chlorophyll-a concentration [A, B, E, F, I, J, L];
 - 3) Determine the presence and composition of aquatic biota, and use rapid bioassessment methods to identify and quantify impact [A, B, D, E, H, I, L];

- 4) Determine the presence and concentrations of heavy metals and other contaminants (e.g., herbicides, pesticides, dioxin, hydrogen peroxide, sodium hypochlorite) in water and /or tissue samples [C, G, I, J, K];
- 5) Analyze water samples for hydrocarbons and other motor vehicle derived contaminants [A, B, N];
- 6) Determine the presence and concentrations of bacterial indicators of fecal contamination, *Giardia*, and *Cryptosporidium* in water samples [E, O];
- 7) Inventory and determine the abundances of light-adapted biota in caves [K];
- 8) Measure groundwater depth and quantity [J];
- 9) Map and photo-archive beach, shoreline, bank and channel profiles and monitor for disturbance (e.g., trampling, soil compaction, rutting, erosion, de-vegetation) [D, N, O];
- 10) Measure ice-levels and the quantity and availability of water in caves [L];
- 11) Measure the presence and amount of litter and garbage at or near resource sites [M].

4. **Introduced/invasive non-native biota:**

A. Monitoring question: What impact do introduced/invasive non-native aquatic biota have on the distributions and survival of native aquatic biota, and on the biotic community and ecosystem dynamics of Klamath Network park unit aquatic resources?

B. Indicators:

- 1) Change in the (a) distributions, (b) abundances, (c) percent area occupied (PAO), and (d) community organization and structure of native and non-native introduced/invasive biota of concern

C. Monitoring Options:

- 1) Determine the status and trends of native and introduced biota including: (a) distributions, (b) abundances, (c) PAO, (d) community organization and structure, and (e) rates of recruitment and mortality;
- 2) Inventory and determine the condition and quality of the habitats occupied by native biota of concern.

5. **Visitor use-recreational** including (a) tour-related impacts, (b) hiking, backpacking and camping, (c) stock (horse) and mountain bicycle use, (d) swimming, sun-bathing, and picnicking, (e) recreational fishing, and (f) motorized boats and boat-related activities:

A. Monitoring question: How do the recreational activities of visitors affect Klamath Network park unit aquatic resources, and how do these activities impact resource condition, quality, and ecosystem dynamics?

B. Indicators:

- 1) Increase in shoreline/bank erosion and concomitant change in nearshore sedimentation rates and siltation;
- 2) Shoreline/ bank soil compaction, trampling, and de-vegetation;
- 3) Change in the distributions and composition of aquatic macroinvertebrates;
- 4) Presence of and/or increase in the concentrations of bacterial indicators of fecal contamination;
- 5) Presence of and/or increase in the amounts of litter and inorganic/organic contaminants.

C. Monitoring Options:

- 1) Inventory and determine shoreline/bank condition and measure, map, and photo-archive indicators of erosion and impact (e.g., (a) sedimentation/ siltation; (b) soil compaction; (c) de-vegetation);
- 2) Collect sediment cores to document historical and contemporary sedimentation rates;
- 3) Measure water clarity and turbidity;
- 4) Determine macroinvertebrate species presence and composition in all aquatic habitats;
- 5) Measure chlorophyll-*a* concentration in phytoplankton and periphyton samples (as a proxy for primary productivity);
- 6) Determine in water samples the presence and concentrations of bacterial indicators of fecal contamination;
- 7) Identify and inventory the presence of litter, as well as inorganic/organic contaminants in caves, and monitor for change.

6. **Atmospheric deposition** of nutrients (e.g., nitrogen and phosphorus) and pollutants (e.g., mercury, persistent organics, flame retardants, water-repellent coatings, etc.):

A. Monitoring question: How does the atmospheric deposition of nutrients and other contaminants affect the water quality and ecosystem dynamics of Klamath Network park unit aquatic resources?

B. Indicators:

- 1) Presence of and/or increase in the concentrations of air-borne nutrients and pollutants;
- 2) Increase in primary productivity;
- 3) Change in the presence and composition of aquatic macroinvertebrates, especially species negatively affected by air-borne pollutants.

C. Monitoring Options:

- 1) Wet/dry chemistry: (a) rain and snow precipitation samples; (b) snow core samples;
- 2) Analyze water samples for nitrogen and phosphorus concentrations;
- 3) Analyze tissue samples (highest trophic-level possible) for the presence and concentrations of pollutants of interest;
- 4) Determine the concentration of chlorophyll-*a* in phytoplankton and periphyton samples (as a proxy for primary productivity);
- 5) Determine the presence and composition of aquatic macroinvertebrates, and use rapid bioassessment methods to identify and quantify impact.

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ATTACHMENT I: Bibliography of Klamath Network Park Unit Aquatic Resources Inventory, Monitoring and Research Study Reports and Publications

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ATTACHMENT II: AQUATIC RESOURCES AND WATER QUALITY QUESTIONNAIRE

1. Name of national park unit covered by this questionnaire:
2. Contact information for the principal person completing this questionnaire:
 - A. Name:
 - B. Position:
 - C. Telephone number:
 - D. Email address:
3. What aquatic resources are present within the park boundary (see next page for list of definitions); have any of these systems/subsystems been inventoried (I), monitored (M) or has research (R) been conducted within any of these systems/subsystems (respond in column 4 with an I, M, and/or R); provide the actual total count for each system/subsystem inventoried, or if not inventoried provide an estimated count, if possible, for each system/subsystem (column 5); in column 6, identify the source of the count in column 5 (I for Inventory, E for estimate).

System	Subsystem	Present in park (Y/N)	I/M/R	Count	Inventory/Estimate
Marine	subtidal				
	intertidal				
Estuarine	subtidal				
	intertidal				
Lotic (streams and springs)	tidal				
	perennial				
	intermittent				

3. continued

System	Subsystem	Present in park (Y/N)	I/M/R	Count	Inventory/Estimate
Lentic	permanent > 8 ha				
(lake, pond, reservoirs)	permanent < 8 ha, > 2m max depth				
	permanent < 8 ha, < 2m max depth				
	intermittent ponds				
Palustrine (wetlands)	marsh				
	prairie				
Ice Caves					
Geothermal					

Definitions of terms associated with 3 above:

1. Marine System: open ocean
2. Subtidal Subsystem: substrate continuously submerged
3. Intertidal Subsystem: substrate is exposed and flooded by tides and includes associated splash zone
4. Lotic System: flowing water
5. Tidal Subsystem: channel gradient is low and water velocity fluctuates under tidal influence
6. Perennial Subsystem: water flows throughout the year
7. Intermittent Subsystem: channel contains flowing water for only part of the year. When water is not flowing, it may remain in isolated pools or surface water may be absent
8. Lentic System: ponds, lakes, and reservoirs
9. Palustrine System: all nontidal wetlands dominated by trees, shrubs, persistent emergent vegetation, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 ‰

5. List past and current water quality monitoring (physical, chemical, biological) efforts within your park. Attach additional page, if necessary.

Brief description of the monitoring effort	Duration of this effort	Who conducted or is conducting this monitoring?			
		a	b	c	d (explain)

Who conducted or is conducting this monitoring?

a = park staff; b = another federal, or a state agency; c = university; d = other

6. List the water resource management issues or land use issues that now impact water resources from either within or outside your park. *Examples* of issues to list include: atmospheric deposition, introduced species, resource degradation due to visitor impact, logging/deforestation, agriculture, grazing, mining, road construction, off-road vehicles, sewage from second homes, boats & personal water craft, urbanization on a park boundary, etc (you may have other issues). Issues also may include “point discharges” into park aquatic systems or their upstream tributaries (note, a “point discharge” is something coming from a pipe or a distinct point of leakage, as opposed to a “non point discharge” from diffuse sources, such as contaminated runoff coming from farm fields. Point discharges also can include public or privately owned treatment works (POTW’s) --i.e., sewage plants. Point discharges also can include EPA designated Superfund Sites. Think in terms of both current impacts to water bodies and future impacts related to growth (industrial, commercial, or residential) or expansion of various types of development. Attach additional page, if necessary.

Issues Within the Park Boundary		Issues Outside the Park (upstream, adjacent to, nearby)	
The Issue (describe the issue and its general location)	Near term or long term?	The Issue (describe the issue and its general location)	Near term or long term?

“**Near term**” refers to impacts that are current or < 3 years away; “**Long term**” refers to potential impacts > 3 years away

7. List the Staff level of experience or interest in water quality monitoring at the park. Identify individuals with a particular interest in water resources or water quality monitoring. If your park has particular outside contacts or sources for water quality and water resource issues, please include them.

Name	Phone	Email	Experience	Expertise

Thank you for your time and effort in completing this questionnaire.

If you have any questions or need clarification, please contact:

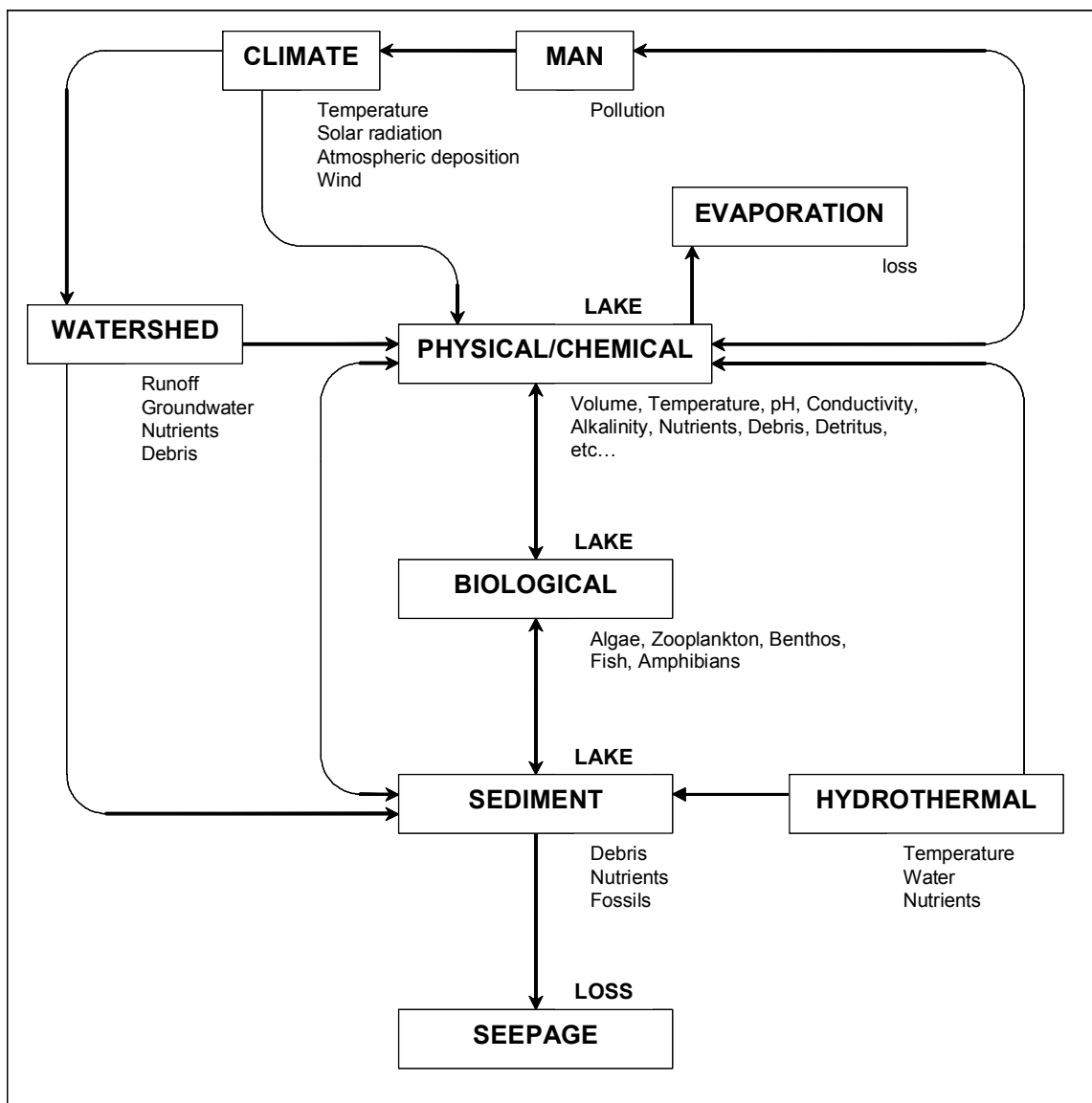
Robert Hoffman: (541) 750-1013 or robert_hoffman@usgs.gov

The questionnaire can be returned to Robert Hoffman via email or snailmail:

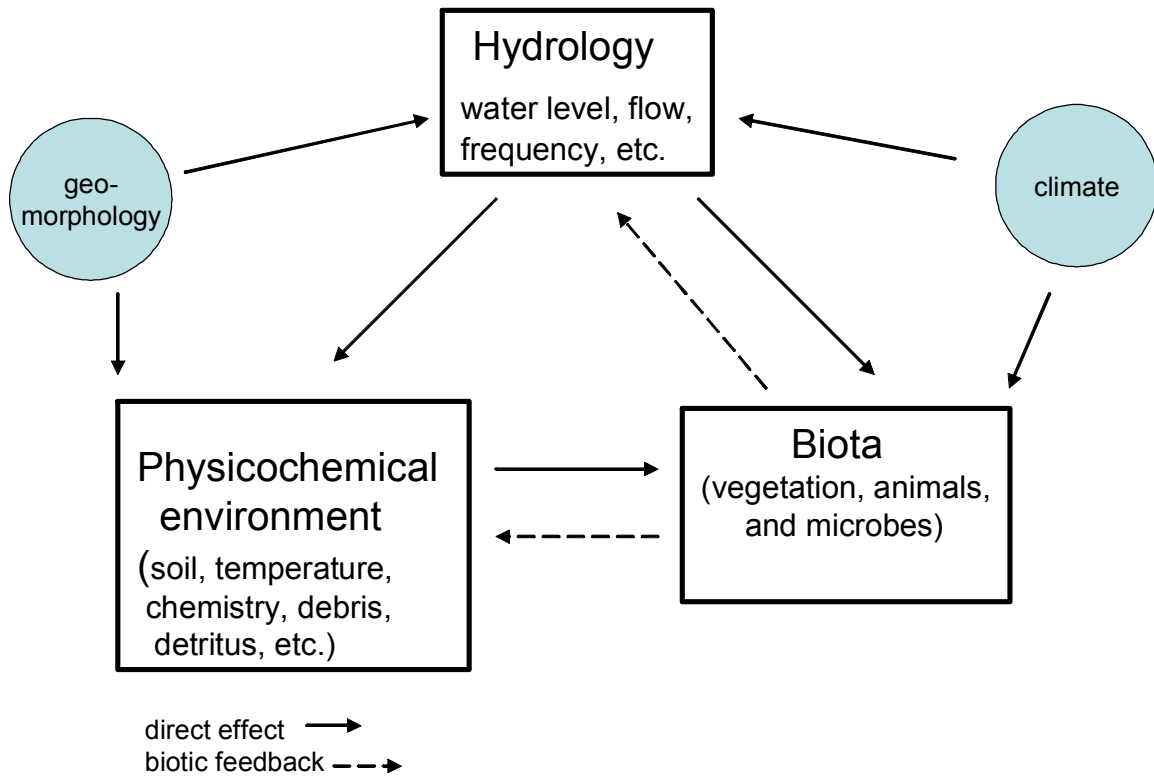
Robert Hoffman
USGS FRESC
3200 SW Jefferson Way
Corvallis, OR 97331

ATTACHMENT III: GENERAL CONCEPTUAL MODELS OF FRESHWATER AND MARINE ECOSYSTEMS

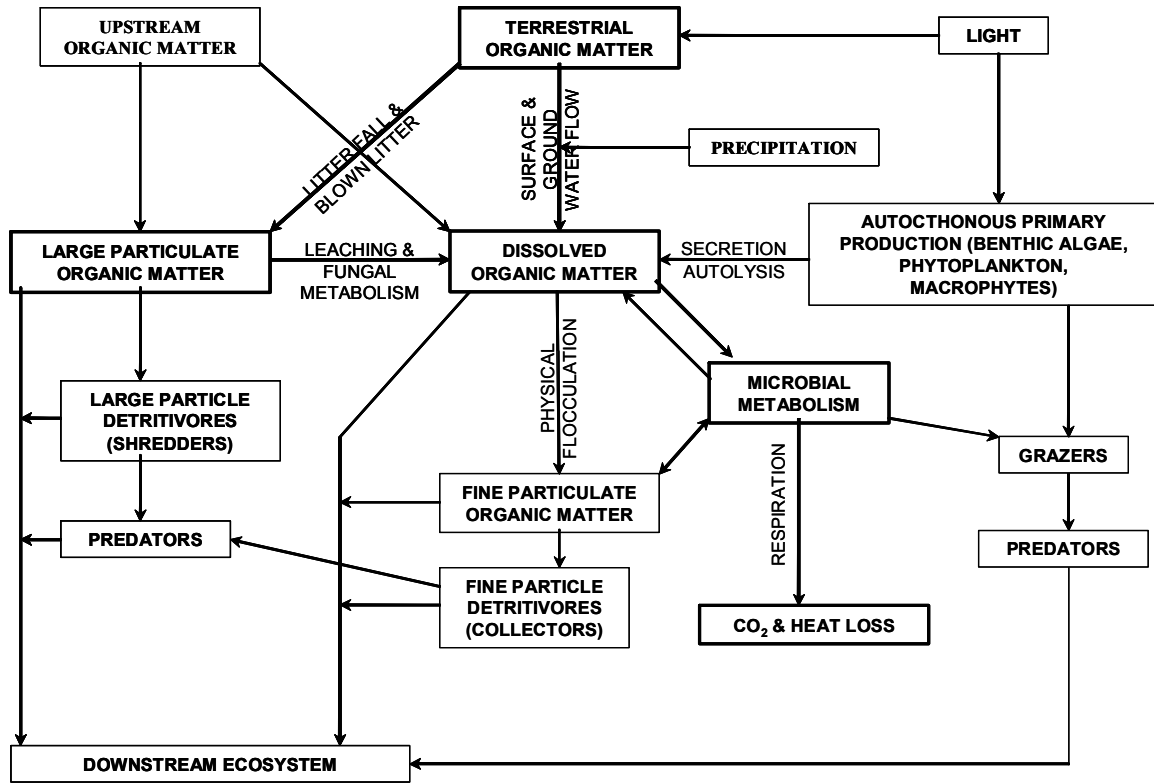
Freshwater lentic (lakes and ponds): after Larson 1990.



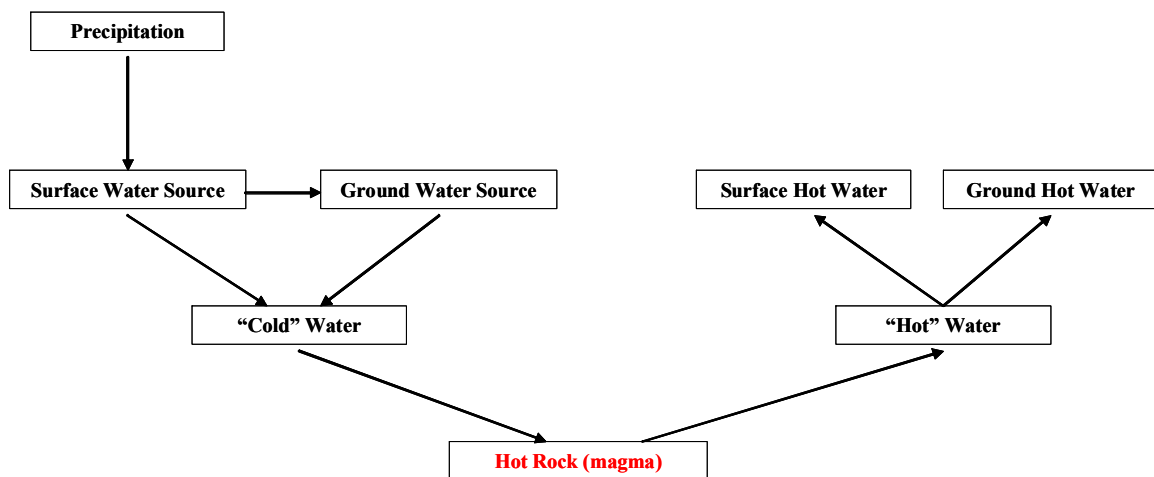
Freshwater lentic (wetlands): after Mitsch and Gosselink (2000).



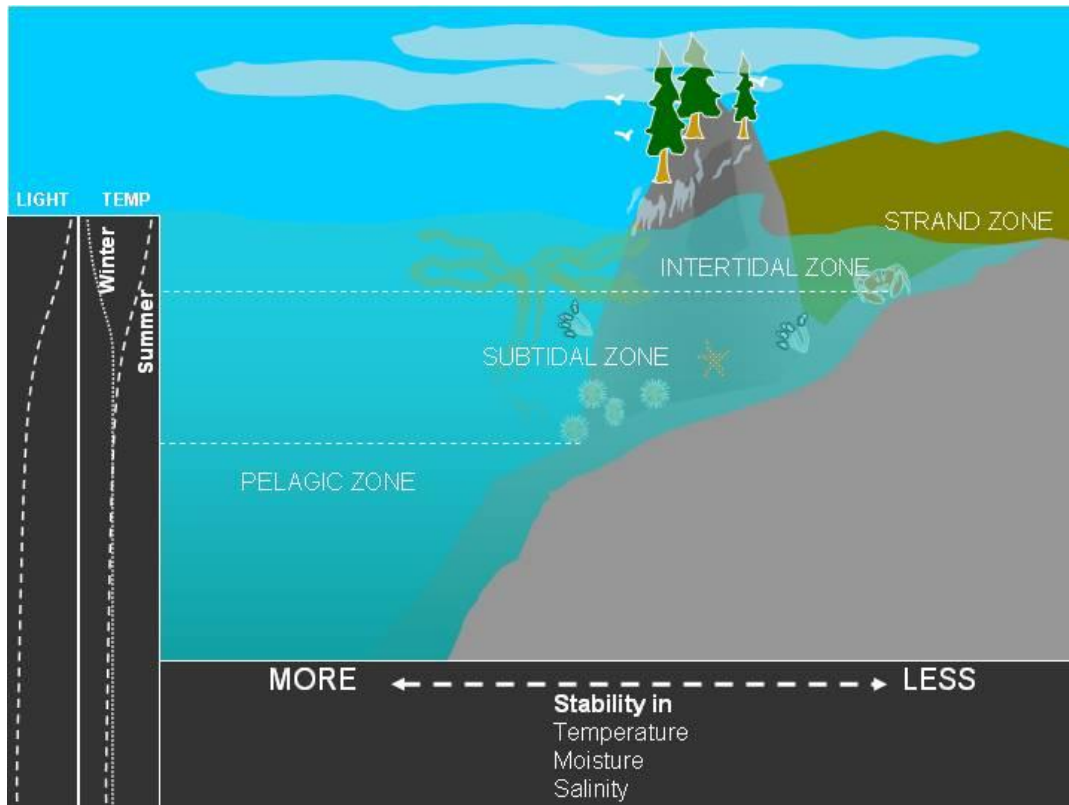
Freshwater lotic (streams and rivers): after Wetzel 1983.



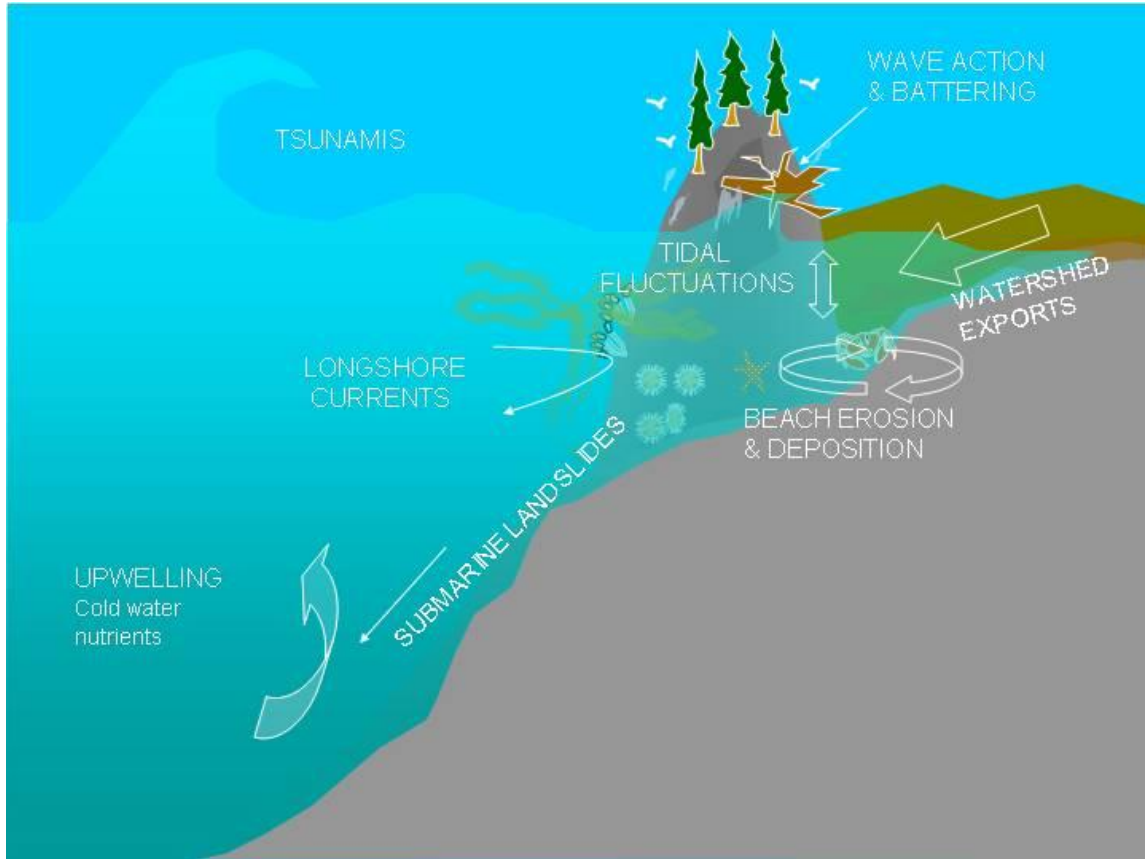
General Geothermal/hydrothermal water model:



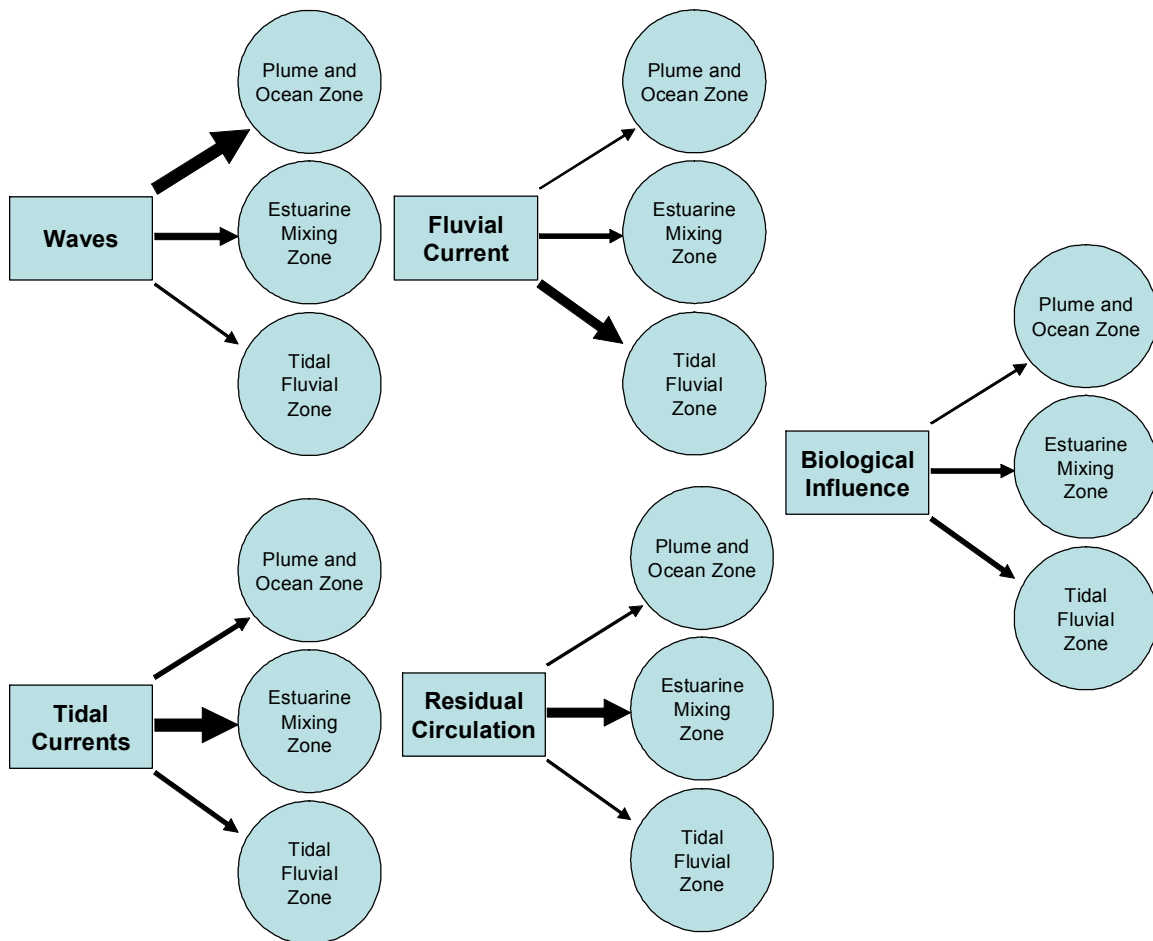
Marine Ecosystem Zonation: Odion et al. 2000.



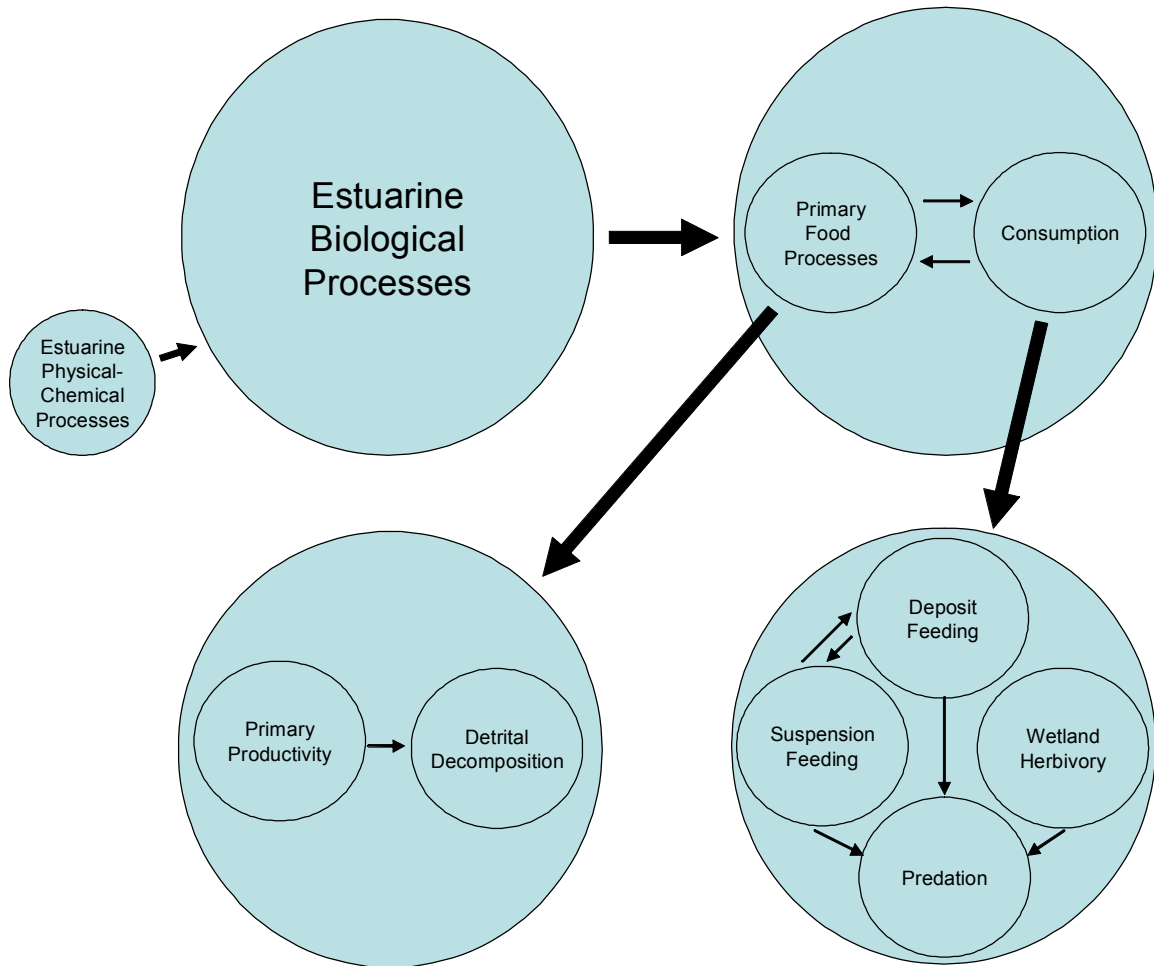
Marine Ecosystem Dynamics: Odion et al. 2005.



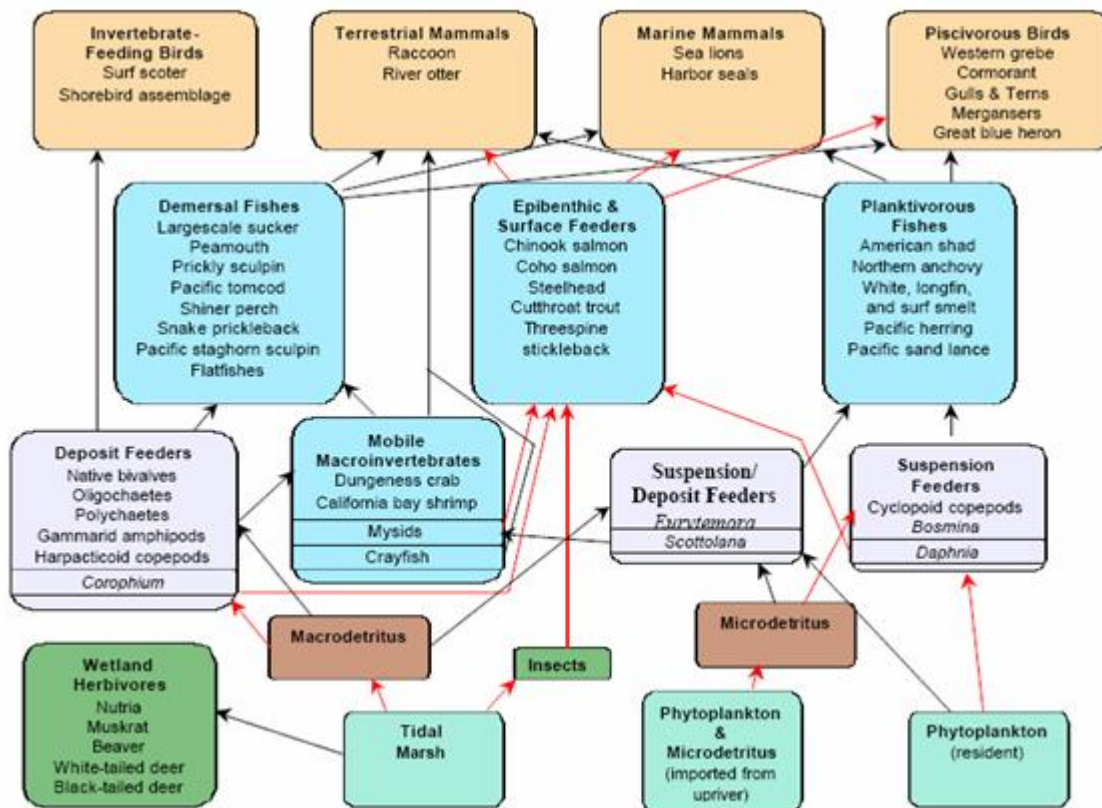
River Estuary: dominant influences on sedimentation and erosion (after Simenstad et al. 1984a). Width of arrow indicates level of impact of influence-type in each of three zones of the Columbia River Estuary.



River Estuary Biological Processes: hierarchical model of the biological processes for the Columbia River Estuary (after Simenstad et al. 1984b).



River Estuary Trophic Groups: simplified representation of major linkages between Columbia River Estuary trophic groups (from Weitkamp 1994)



Lagoon Estuary: model structure for nitrogen cycling (after Webster & Harris 2004). DIN = dissolved inorganic nitrogen; DON = dissolved organic nitrogen.

